CSG A GREENER TOMORROW

Comprehensive Organizational and Socialistic Report

ABSTRACT

The reasonable man adapts himself to the world; the unreasonable one persists in trying to adapt the world to himself. Therefore, all progress depends on the unreasonable man (Shaw, 1903).

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1. Introduction

Humans have altered environments and enhanced their well-being unlike any other creature on the planet (Hielman & Donda, 2007); this is no different whether the environment is ecological, social or organizational. In recent times, the debate regarding greenhouse effects on the global weather patterns and the sustainment of the earth's temperature necessary for life support has become quite infamously problematic as society pushes to find new sources of energy both renewable and environmentally sustainable. The feedback received on CSG from both government and companies alike is that the opportunities this industry creates has a lasting range of social and economic benefits worth over fifty (50) billion dollars in projects (Queensland Government, 2013). This however, has been overshadowed by social activist and lobbyist groups as 'Lock the Gate Alliance' saying, as one part of their report noted from the National Water Commission, "coal seam gas development could cause significant social impacts by disrupting current land-use practices and the local environment through infrastructure construction and access" (Lock the Gate Alliance, n.d.), and "In recent years both a NSW and Federal Senate inquiry into coal seam gas production were deliberately mislead by an organization that claims to work on behalf of the farming community, This is the battle for the end of the fossil fuel industry. This is the end game..." (Ward, 2013).

Various academics have documented the benefits and consequences of Coal Seam Gas. Leo, Anderson and Meis-Mason (2009) conducted research on coal seam gas and oil into long-term environmental and social impacts as well as the short-term development impacts of the Canadian Northwest Territories during the last one hundred (100) years. Coal Seam Gas and Oil was found to bring benefits as well as consequences to the following area:

1. ***Environmental:*** Consequences from the oil and gas mining were local tribal food supply and also with harmful pipeline spills had a widespread impact on land, vegetation and animal life.
2. ***Economically:*** Benefits from the oil and gas mining to the community was the money which was injected into localized areas, also new infrastructure and businesses.
3. ***Social:*** Consequences from the oil and gas mining to the local communities at the time saw families fall apart due to the introduction of drugs and alcohol, as well as many men working from down south who lured the local woman with unfilled promises resulting in many single mothers.

This paper aims to provide a grounding into the links between coal seam gas organizational profitability, environmental effects and impacts on society, as well as the possibility of giving some direction should future economic consideration is to be placed on coal seam gas more readily as a greener solution. The paper is structured in the following manner:

1. **Coal Seam Gas**
   1.1. The materials composition extracted
   1.2. Established mining and extraction techniques
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2. **Coal Seam Gas Economic Outlook**
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   3.2. Organizational legislative requirement & Regulatory Bodies

4. **Coal Seam Gas Social Outlook**

The first section will cover coal seam gas general information. The section will be followed by csg economic information, followed closely by csg environmental impact and legislative requirements. Finally, the examination of csg social impacts will focus on the effects the industry due to social media and half-truths. Following this section, the paper conclusions and limitations shall be presented in the last section.

2. Coal Seam Gas

a. The Materials Composition extracted

Coal formed from the process of ‘coalification’, undergoing several physical and chemical alterations as result of bacterial decay, compaction, heat and time within an oxygenated organic rich water supply (Wang, 2012). The stages by which the decay process are anaerobic or aerobic, create the following coalification according to Wang (2012) through various phases:

- **Peat:** A heterogeneous mixture of decomposed plant remains to a fine amorphic, colloidal mass accumulated in a water and oxygen saturated environment (Clarke & Joosten, 2002).
- **Lignite:** A brownish-black combustible mineral formed during phase one from peat, an increased pressure and temperature airless atmosphere, with approximately the following characteristics (Lignite Energy Council, n.d.) (Radovic, 1985) (KET, 2005) :
  - 60,000,000 years of age;
  - 25-45 percent of carbon; and
  - 7,385,390.9683 joules (7,000 Btus) per 0.453592 kilograms (1 pound).
- **Sub-Bituminous Coal:** A dull, dark brown combustible mineral formed during phase two from lignite, an increased pressure and temperature airless atmosphere, with approximately the following characteristics (U.S. Department of Energy, 2013) (KET, 2005) (Radovic, 1985):
  - 100,000,000 years of age;
  - 35-45 percent of carbon,
  - 10,550,558.5262 joules (~10,000 Btus) per 0.453592 kilograms (1 pound)
- **Bituminous Coal:** A dense dark-brown to black combustible mineral formed during phase three from sub-bituminous coal, an increased pressure and temperature airless atmosphere, with approximately the following characteristics (U.S. Department of Energy, 2013) (KET, 2005) (Radovic, 1985):
  - 300,000,000 years of age;
  - 45-86 percent of carbon,
  - 20 percent moisture
  - 12,660,670.2314 to 15,825,837.7893 joules (12,000 to 15,000 Btus) per 0.453592 kilograms (1 pound)

- **Anthracite Coal:** A brittle, lustrous black combustible mineral formed during phase four from bituminous coal, an increased pressure and temperature airless atmosphere, with approximately the following characteristics (U.S. Department of Energy, 2013) (KET, 2005) (Radovic, 1985):
  - 350,000,000 years of age;
  - 86-96 percent of carbon,
  - 15 percent moisture
  - 15,825,837.7893 joules (~10,000 Btus) per 0.453592 kilograms (1 pound)
- **Graphite:** A sub-metallic, steel-grey to iron black metalloid formed during phase four from anthracite coal an extreme pressure and temperature airless atmosphere, with approximately the following (Ralph & Chau, 2013) (Papineau, et al., 2011):
  - 300,000,000 to 4,200,000,000 years of age;
  - 100 percent of carbon,
  - 1-2 Mohs Hardness with an amorphous crystal structure
- **Jet:** A jet black mineraloid formed during phase four from wood anthracite coal an extreme pressure and stagnant salt-water atmosphere, with approximately the following characteristics (Amethyst Galleries Inc, 1995) (O'Donoghue, 1990):
  - 300,000,000 to 350,000,000 years of age;
  - 100 percent of carbon,
  - 2.5 Mohs Hardness with an amorphous crystal structure

Today, quality of coal not only impacts pollution emissions, but also the boilers, affecting combustion, stability, corrosion, ash deposition and disposal in coal-fired power plants (Yin, Zhang, Dong, Ma, & Jia, 2009). To help avoid this the introduction of laser-induced breakdown spectroscopy (LIBS) has been experimented with allowing for coal sample composition quality and breakdown into Carbon (C), Silicon (Si), Aluminum (Al), Calcium (Ca), Magnesium (Mg), Titanium (Ti) and Iron (Fe) percentages aimed at designing a system that captures LIBS advantages to proximate analysis of pulverized coal (Yin, Zhang, Dong, Ma, & Jia, 2009). The instrumentation consists of the LIBS apparatus and sampling equipment as seen in Appendix A this allows for the use of the Bode Rule for more quantitative analysis and yielding of accurate measurements to minimize matrix effected caused by uncertain evens, such as coal particle sizes, undesired aerosol events, rough coal powders, etc. during plasma formation (Yin, Zhang, Dong, Ma, & Jia, 2009). Through the introduction of laser-induced breakdown spectroscopy this could allow for more accurate assessment and placement of coal seam gas wells globally.

Coal Seam Gas also known as Coalbed methane (CBM), Unconventional gas or Sweet Gas, alternative names due to the differing methods used for extraction or position within coal or earth formation are shale or natural gas. These are all reminisce from either anaerobic or aerobic decay process, containing 90-94% methane with a similar calorific value of 979 Btu/cf with the remaining 6-10% consisting of ethane, propane, butane, and pentane, carbon dioxide, and nitrogen (Lyons, 1996) (Gallagher, 2006), a full CBM breakdown has been provided as part of Appendix B (Gallagher, 2006) CBM is considered an unconventional form of natural gas because the coal acts both as the source of the gas and the storage reservoir, in which the gas is primarily adsorbed on the molecular surface of the coal rather than stored in the pore spaces as in conventional gas reservoirs (ALL Consulting, 2003) (Alberta Geological Survey, 2013). The volume of CBM extracted from a coal seam reservoir is dependent of various dynamics such as chemical composition of coal, geological history and previous depressurization due to natural occurrence, for more precise yield estimation laboratory drilling samples and gas release volume-pressure measurement testing is implemented for economic investigation (Alberta Geological Survey, 2013).

Globally and nationally CBM geographical distribution is centralized around four major continental breakdowns Asia-pacific, Americas, Africa and the Middle East.

b. Global & National CBM geographical distribution

Stipulated above the breakdown as shown in Appendix C among the four major continental breakdowns the largest CBM reservoir bases lie in Russia, Canada, China, Australia and the United States of America (Sloss, 2005). In 2006 an estimated global CBM recovery yield was estimated to total 143 trillion cubic metres, with only 1 trillion cubic metres actually being recovered from global reserves (Sloss, 2005). Since 2006 the World Energy Council has revised this figure to approximately 176.462 Trillion cubic metres (Zupanic, et al., 2007) with still the highest estimated CBM resource bases being as follows with a full global breakdown in Appendix D:

Country	Estimated CBM Resource Base (trillion cubic metres)
Canada	17 to 92
Russia	17 to 80
China	30 to 35
Australia	8 to 14
USA	4 to 11

c. Established mining, extraction and conversion techniques

CBM production relies in several varying factors which differ from geographical location and basin to basin, with such being fracture permeability development, gas migration, coal maturation, coal distribution, geological structure, CBM completion options and produced water management (ALL Consulting, 2003). In most basin areas CBM development occur where natural fracture network have high-quality geological structures and localized faulting allowing for more induced natural fracturing leading to increased production pathways within the coal seam (Figure 2) reducing costs of bringing production wells-online (ALL Consulting, 2003) (Lyons, 1996). In coal fractures contain porosity but very little matrix permeability, however, within coal seam gas wells the coal process contains a system of secondary permeability fractures allowing water, gas and other fluids to migrate from matrix to the producing well. These secondary permeable fractures are known as a cleat network resulting from coal dehydration, local and regional stresses, unloading overburden, creating continuous and laterally extensive face cleats to maximum compressive stress and perpendicular to fold axis, with the Butt cleats used as a strain release (ALL Consulting, 2003) as seen in figure 1.

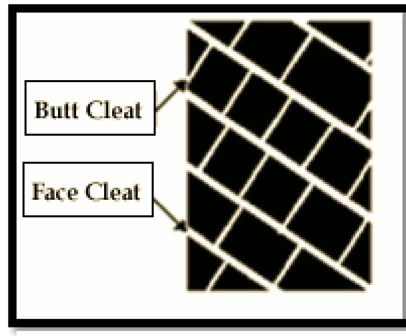


Figure 2: Basic Cleat (Fracture) Breakdown

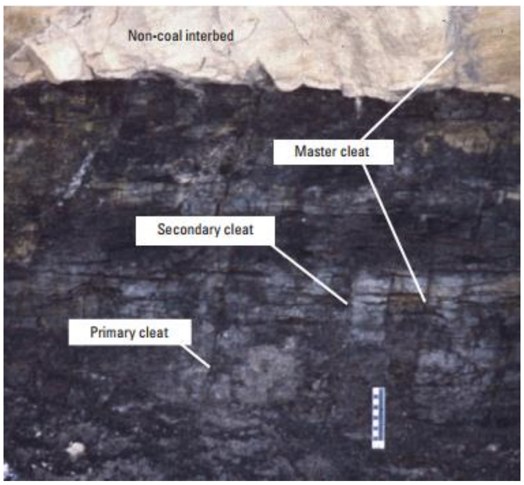


Figure 1: Cleat Photo of Coal Seam Wall

To help better enhance mining and extraction yield as well as overall return on investment organizations employ numerous laboratory drilling samples and gas release volume-pressure measurement tests in addition to numerous analysis tests as such petrology, geochemistry and gas content analysis to determine economic value and overall cubic metre yielding (Alberta Geological Survey, 2013) (Weatherford Laboratories, 2013)

i. Evaluation Methods

When a company is able to accurately determine the volume of gas-in-place and gas recovery from the Coalbed methane reservoir it helps to make more efficient and informed production decisions (Weatherford Laboratories, 2013). Standardized techniques in which CBM can be evaluated through mechanically disaggregate core samples, or according to Weatherford Laboratories (2013) more critical coal bed analysis such as:

1. **Gas Content Analysis –** Allows the analyzer to determine the total volume of gas present in a freshly cut core sample;
2. **Wellsite Canister Desorption –** A primary tool to quantify the volume and quality of gas to determine commercial potential;
3. **Desorbed Gas Composition –** Identifies the fractionation of gas over the life of the desorption history to determine a total in situ gas composition and the need for multiple gas isotherm data ;
4. **Adsorption Isotherm –** Accurately determines the volume of gs that can be stored through sorption at reservoir temperature and pressure conditions;
5. **Clastic Sedimentology –** classifies interburden and depositional environment;
6. **Maturity Assessment –** determines coal rand and aids in the determination of coal properties;
7. **Effective Permeability** – Determines through well testing the key property controlling gas producibility of CBM reservoir;
8. **Gas Saturation** – Combining gas content and gas storage data predicts the critical desorption pressure (CDP) when CBM gas production will start; and
9. **Gas In Place –** Predicts the total volume of gas in the reservoir through (1) the area of coal beds, (2) the thickness of the coal and carbonaceous shale, (3) average coal-bed interval density, (4) and in-situ gas content. These three values can be determined via log data or core samples with a fourth parameter in-situ gas content varies widely and is most accurate if measured directly on fresh core samples. The use of the fourth parameter allows for burial history reconstruction and gas generation models to compute theoretical values. Whereas more experimental methods uses adsorption isotherms to give a value, however, this method is sometimes flawed with higher errors should the gas-in-place figures show corrected moisture and ash content of the coal. Both Theoretical and Experimental methods account for non-coal components calculating the coal mass to determine the GIP (Dallegge & Barker, n.a) (Weatherford Laboratories, 2013).

   The basic formula which is used to help determine Gas-In-Place is as below:

$$GIP = CM_{coal\ mass} \times G_{Gas\ content}$$

$$CM_{coal\ mass} = Z_{coal\ zone\ thickness} \times A_{area} \times D_{density}$$

The two methods described above Yield very different results such as experimental gives a minimum value for GIP as it uses weathered coal samples from ether col outcrops or aged well core, which reduces sorption capacity. Whereas, the theoretical method gives a moderate GIP value in low-rank coals because the modeled volume of gas generated has not exceeded the sorption capacity of the coal (Dallegge & Barker, n.a) (Lyons, 1996).

The use of the above evaluation methods allows for coal basins to be measured more accurately with as content figures ranging from several hundred standard cubic feet (SCF) per ton of coal to less than 50 SCF per ton of coal, however, it is important to note the equated numbers are not the ultimate recoverable CBM reserves since not all gas can be desorbed and produced from the coal (Dallegge & Barker, n.a) (ALL Consulting, 2003).

ii. Mining and Extraction Techniques

CBM can be classified according to Kumar and Matthews (2008) upon the nature of extraction which can be classified into three main groups:

- **Pre-mining Methane –** Methane which has been stored in virgin coal seam which is extracted prior to mining activities
- **Coal mine methane (CMM) –** a subset of CBM that is released from the coal seams during mining activities
- **Post-mining methane** – Methane which is recovered from the goafs, gobs and abandoned mining areas.

CBM extraction methods are generally placed into two separate categories in which these are:

- **Pre-mining drainage methods –** These methods involve drilling of boreholes or bore wells from the surface into virgin coal seam, which is generally ineffective in low permeability seams, thus to increase permeability the use of hydrofacture, blasting and chemical reactions are implemented (Gallagher, 2006) (Kumar & Matthews, 2008) in addition to pumps which create a vacuum for better methane recovery.

  The above three mentioned methods to help increase the permeability of coal seam for improved CBM extraction, have been explained in short detail below:
  - ***Hydrofracturing-*** High pressure water and sand mixture are in injected into the coal seam through bore holes, developing new cracks and widening existing cleats/fractures stimulating methane production (EPA, 2012). This process is further explained through Appendix E (Harbour, 2011)

- ***Blasting –*** A difficult to justify method due to the risk of above ground destabilization, due to a large explosive charge being positioned deep within boreholes and detonated (Kumar & Matthews, 2008).
- ***Chemical Reactions –*** A weak hydrochloric acid could be also injected into the coal seam to react with minerals present, however, the removal of minerals may enable confining stress on the seam to close the cleat (ALL Consulting, 2003).
- ***Vacuum technique –*** This technique, utilizes specially designed pumping equipment installed in a bore-hole, to remove coal seam water and to start sucking out coal seam, however, this technique has resulted in lowering water levels in nearby strata (U.S. Department of Energy, 2013) (Kumar & Matthews, 2008). This system is shown and simply explained in Appendix F.

In addition to these techniques Kumar and Matthews (2008), as well as Liu, Dunn and Hatherly (1998) have defined the followed extraction methods for pre-mining drainage (*Note: Added resource material evidence provided where required*) are described as follows:

- **In-seam drain from underground boreholes –** This technique works in moderate to high permeability, allowing for borehole yielding between 0.1 to greater than 60 m^3 / day gas flow equating to 100L/s. These equated gas flows are caused by boreholes intersecting the main joints (cleats) in a coal seam parallel to the cleat direction, however, at a right angle drainage in larger volumes maybe achieved. In figure 3 a typical production curve for a CBM well showing relative methane and water production shows idealistic parameters when prior consideration is given to:
  - Borehole location
  - Borehole length
  - Borehole space
  - Collection system; and
  - Time available for drainage

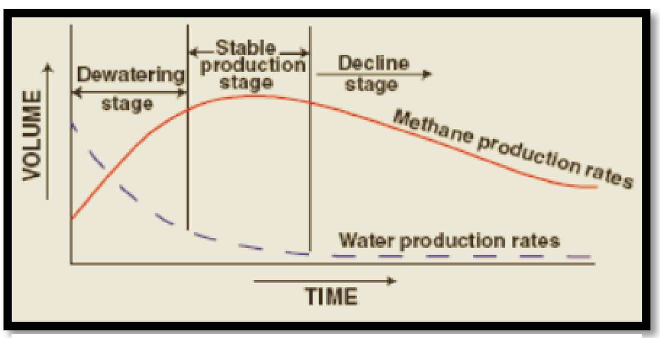


Figure 3: Water & Gas release time scaling

- *Horizontal in-seam borehole (in-seam sub-category)* – this method is utilized with success in longwall face mining in which boreholes are usually installed to function for periods of twelve months or less than two years, approximately 76 m apart from the tail gate entry to the road way as displaced in figure 4.

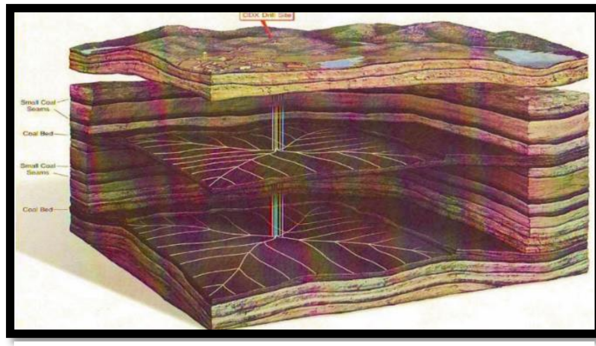
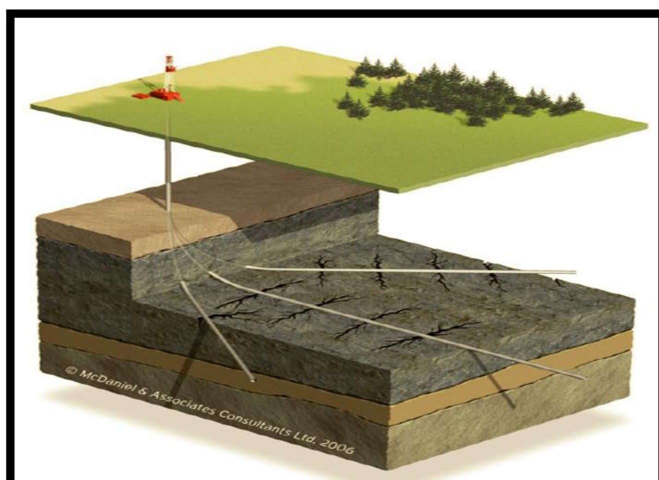


Figure 4: Horizontal in-seam borehole

- ***Short boreholes in the mine roof (in-seam sub-category)*** – boreholes which are drilled into the roof of heading to control emission of methane from discrete fractures in gas bearing sandstone, where there is a frictional ignition risk mechanized drivages or drilled ahead of face to release gas before mining is advanced
- ***Long horizontal in-seam boreholes (in-seam sub-category***)- Longwall panels are installed prior to the development of horizontal boreholes steered in-seam boreholes to effectively reduce in-situ CBM contents in advance of mining in low to high permeability of coals, as well as be used to drain faults and fissures containing CBM.

- **Pre-mining drainage from surface boreholes** – Vertical bore-holes drilled from the surface into multiple coal seams, and injected if coal seam is not permeable with a technique known as 'Blow Down' in which high-pressure fluid or air is injected fifty times over eight to ten days lasting about fifteen minutes. This method is showing in Figure ……. However, due to this being non-uniform in nature it is not highly practiced.



- **Post-mining drainage methods–** Tis method was developed in Germany approximately forty years ago, but has been considerably refined, as it involves drilling boreholes angled above and in some instance below the goaf, close to the coal face and connect to them a piping network , assisted by a suction pump sited either underground in a return airway or a surface in a purpose built methane plant (United Nations Economic Commission for Europe Methane to

Markets Partnership, 2010) (Sloss, 2005) (Kumar & Matthews, 2008). These drainage methods are briefly defined as follows:

- ***Underground cross measure methane drainage –*** Boreholes are drilled t angles above or below the goaf from the return airway of a long wall face and connected to a methane removal system. Largest methane flows usually rise from the roof by a few metres, with significant recovery of CBM approximately twenty four to twenty six metres behind the face, resulting in around 50 – 70 % methane capture while range percentage varies 30-50 % nearing retreat coalface (Mutmansky, 1999) (Kumar & Matthews, 2008) (Creedy, Saghafi, & Lama, 1997).
- ***Gas drainage borehole in the roof –*** A zone age in the immediate roof of the workings that typically extends between five to twenty metres, where the degree of fracturing precludes satisfactory sealing of a gas drainage borehole. Steel piping is therefore used to line the immediate section of the borehole, drainage is generally not effective if the pipe length is extended beyond fifty metres (Creedy, Saghafi, & Lama, 1997).
- ***Drainage to the surface using vertical goaf wells –*** A venting borehole is drilled to within a short distance of the seam to be worked (Creedy, Saghafi, & Lama, 1997), sometime extended with a smaller diameter open hole drilled through the work seam horizon before or after the coal face as passed as seen in the below summary image. The productivity length of the borehole is sometimes lined with slotted pipes, this is an applicable methane recovery method for shallow longwall, room and pillar mining, as these vertical wells produce more methane when a longwall face is distressed (Creedy, Saghafi, & Lama, 1997) (Liu, Dunn, & Hatherly, 1998).
- ***Goaf drainage from underlying or overlying roadways –*** This is called superjacent heading Hirschback method, which was developed in the Saar coalfield, Germany by which a methane drainage roadway would be situated 20-25 m above the worked seam or less than 20 m below (Creedy, Saghafi, & Lama, 1997).
- ***Goaf drainage using long horizontal boreholes above or below the worked seam –*** A successful technique in Australia, in which a borehole is drilled in a competent horizon at twenty to thirty metres above or below the worked seam for the length of a projected long wall panel. A borehole started from the work seam can be guided through an arc to run parallel to the working at a selected horizon above or below the drilling site (Creedy, Saghafi, & Lama, 1997) (Kravits & Li, 1995).

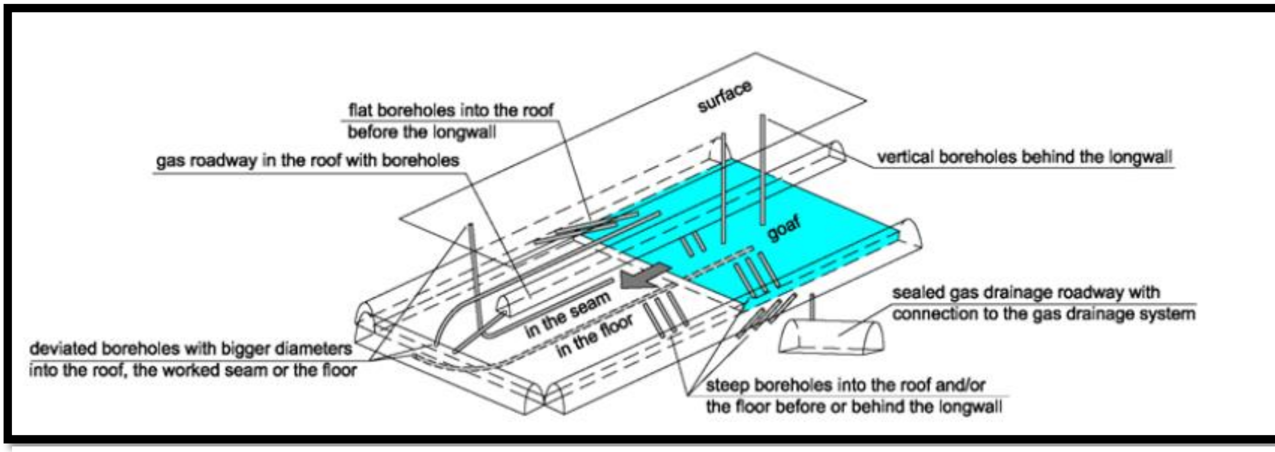


Figure 5: Post mining drainage methods

Gas capture and use in coal mines, was first recorded from the minds of the UK in 1730, advancing to systematic and effective gas capture methods in the 1950's and since the 1960's enhanced mine boilers, additional technology and industrial processes advances for drained gas usage. In Appendix G a three-dimensional schematic in cut away perspective, f an underground coal mine workings and surface facilities shows the complexity and interrelated aspects of a mine drainage and gas collection systems with surface facilities needed to convert CMM to electricity.

iii. Purification Techniques

The typical process for CBM purification, according to Kravtis and Li (1995), Tetlow-Smith (1995) and Kirkby (2011) process line includes:

- Removal of oil and condensates by cooling and settling.
- Removal of water by absorption in a diethylene glycol tower followed by adsorption in zeolites
- Removal of propane and butane by absorption and fractional distillation
- Removal of ethane by cryogenic techniques, after distillation, this is useful in the petrochemical industry.
- Removal of sulfurous gases and carbon dioxide by absorption in monoethanolamine, however, in cases where the sulfur content is high, it may be economically viable to separate it.

The purification plant is an important infrastructure placement as one plant may serve many CBM wells over a considerable area, with an intricate interconnecting small bore pipework often made of cast iron pipes (Liu, Dunn, & Hatherly, 1998). At the wellhead, there is a 'tree' for initial separation of gross impurities, including sand, should gas still contain impurities these maybe highly corrosive, especially from 'sour' gas with high vapor and sulfur content (Tetlow-Smith, 1995).

d. CSG water purification techniques and distribution

CBM gas recovery techniques are unique compared to other production methods, as formation water must be removed, or 'dewatered' as it holds the methane gas in the coal seam by hydrostatic pressure (URS, 2012). Initial volumes of water are very high decreasing rapidly to allow for the release of methane gas, however much of the water can be disposed of by direct discharge given the high quality of CBM (Siemens, 2011). Lower quality water , however, must be managed depending on environmental compliance and economic objectives, this would include volume of produced water which was to be treated, proximity of surface water, right of way, influent chemistry, discharge quality requirements, and use provisions (private or public) and recycle objectives (Siemens, 2011) (URS, 2012).

No two wells or coal seams behave identically and water production can vary from a few thousand to hundreds of thousands of liters a day, depending on the underground water pressures and geology (CSIRO, 2012). Queensland, water production has on average, to date, is approximately 20, 000 Litres per well per day (CSIRO, 2012) equating to between75 – 100 GL / year, however, water production by the year of 2030 (McCusker & Quinlan, 2013). The water is generally high in chloride content with typical values ranging from 1100 to 3000 mg/l which means it cannot be discharged to local watercourses due to the negative impacts on agriculture and river life. This translates as a requirement for water treatment facilities, infrastructure and engineered solutions to deal with the clean discharge water and the concentrated brine that are the process outputs (McCusker & Quinlan, 2013).

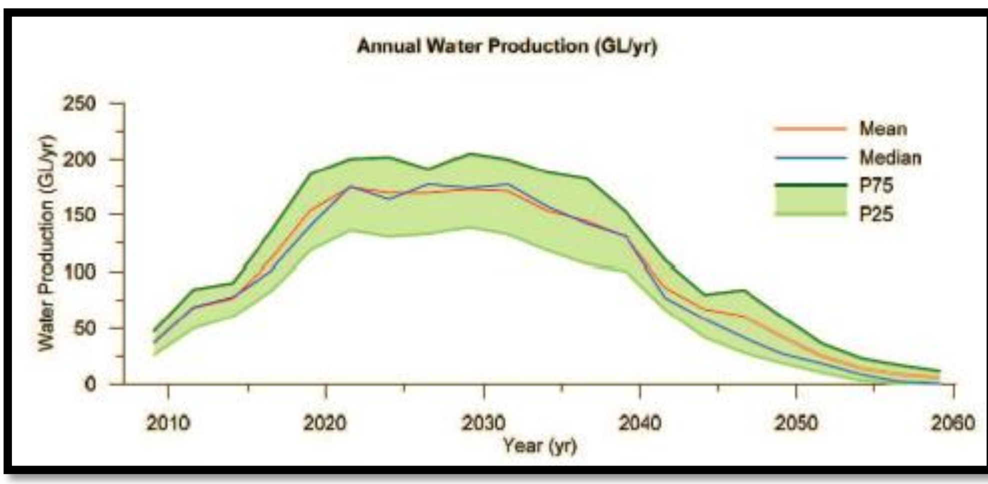


Figure 6: Estimated water production in the Surat and Southern Bowen Basins

The key components to water treatment infrastructure according to McCusker and Quinlan (2013) bring into light two 40 ML/ Day water treatment facilities and associated facilities such as raw and treatment ponds, which are double lined and designed to provide (McCusker & Quinlan, 2013) (Siemens, 2011):

- Buffering capability to average out changes in product water quality and composition;

- Feed ponds to provide minimum retention time and temperature stabilization in addition to allowing carbon dioxide and other residual emissions; and
- Brine storage to accommodate concentrated brine.

The ponds feed the treatment facilities which are designed to treat the associated water to predetermined parameters allowing it to be reused as irrigation, stock watering, portable water supply supplementation and potential re-injection for managed aquifer recharge.

The main treatment processes which are implemented within current industrial practice are:

- **Disc & Micro filtration –** Designed to filter water through a simple mechanical process involving mechanism of adsorption (physical and chemical) straining, sedimentation, interception, diffusion and inertial compaction. Filtration spectrum ranges from ST Micrope to Visible by naked eyes, as illustrated within Appendix H helps to extract everything from metal ions to beach sand. The different types of filtration are as follows allowing for differing types of water purification at different levels these are:
  - **Slow sand filters,** a sand loaded at low flow rates between (0.05 to 0.2 m/h), with differing sample spreads which may see placed into two methods seeing it as gravity or pressure based, by which raw water may lie for several hours for particle settlement or to enhance this rapid filters may be used in conjunction as in chemical treatment, flocculation, and sedimentation to remove impurities from raw water (Huisman & Wood, 1974). Slow filtration filters are often referred to as 'biological' filters using various elements that together as seen in figure 7, and each part summarized .

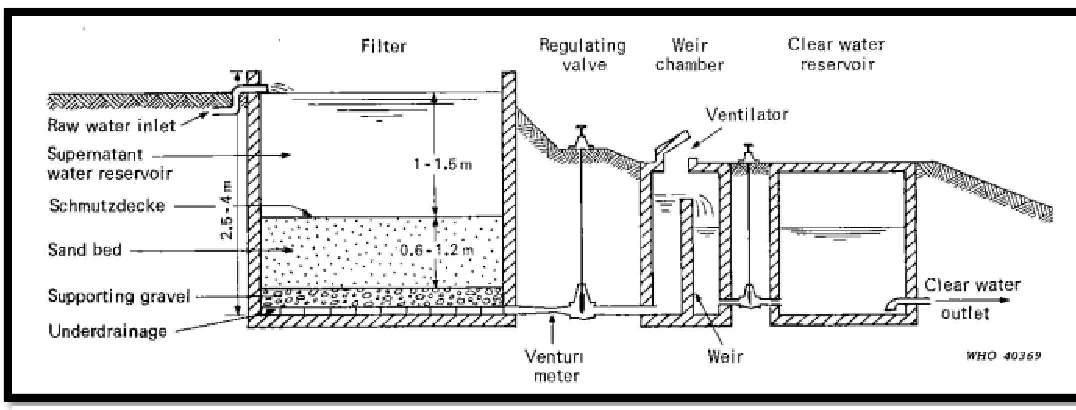


Figure 7: Slow filtration system breakdown

- The 'Supernatant Water reservoir', the principal function is maintaining a constant head of water above the filter medium, this head provides the pressure that carries the water through the filer (Huisman & Wood, 1974).
- The 'bed of filter medium' (nearly always sand), provides the various purification process (Huisman & Wood, 1974).
- The 'under-drainage system', which fulfills the dual purpose of supporting the filter while presenting the minimum obstruction to the treated water as it emerges from the underside of the filter-bed (Huisman & Wood, 1974)..

- The 'system of control valves', regulate the velocity of flow through the bed, to prevent the level in the raw water reservoir from dropping below a predetermined minimum during operation, and to permit water levels to be adjusted and backfilled (Huisman & Wood, 1974).

- **Rapid sand filters,** is a technique common in developing countries for treating large quantities of drinking water as the process is relatively sophisticated as it requires power-operated pumps for backwashing or cleaning filter bed, and flow control of the filter outlet (UNEP, 2013). Due to continuous operation of the filter there will be a requirement of every two days when raw water has a low turbidity backwashing is to occur helping to clean out filter bed. Relatively large quantities of filter backwash water, as well as sludge may be generated and required to have treatment before discharge into the environment.

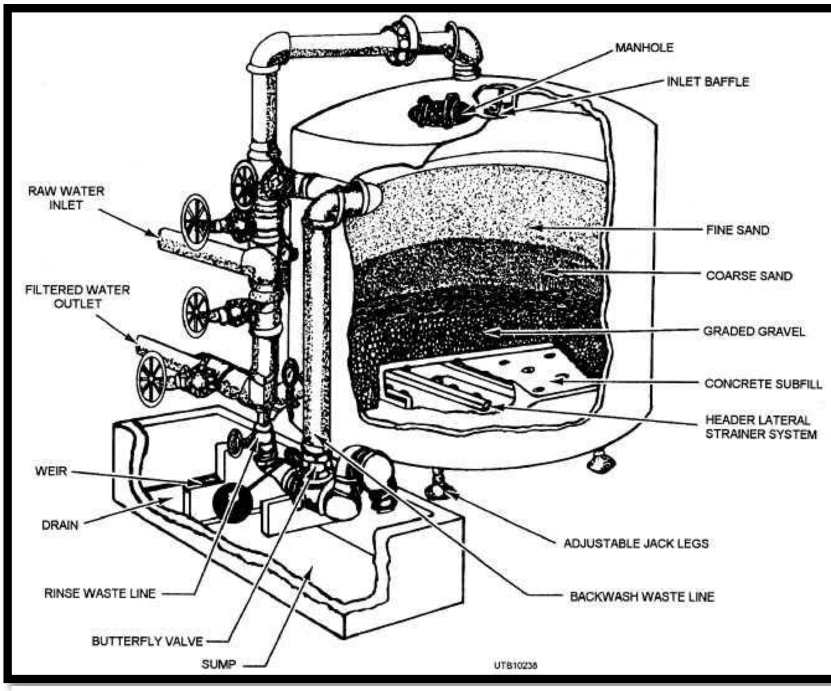


Figure 8: Fast filtration system breakdown

The rapid sand filters are used in some larger, urban and sometimes mining water systems in SIDS, in which the systems utilize rapid gravity filters, allowing for treatment between 57,000 m^3/day in places such as Mauritius (UNEP, 2013). Higher filtration rates, yield a reduced area requirement of approx. 20 percent of that required for a slow sand filter (UNEP, 2013).

Slow and rapid filtration filters are dependent on the volume of water, plant requirements and location as well as if the water is to be used in urban or rural areas, as described above and seen in Appendix I the different processes either are time based due to shorter treatment processes or shorter with more process steps (Cheremisinoff, 2002).

- **Membrane Filters or 'membranes'** – is a microporous plastic film as seen in figure 9 with specific pore ratings, also known as a screen, sieve or microporous filter, which retain particles or microorganisms larger than their pore size primarily by surface capture (Bonnet, 2013). As seen in Appendix J A relatively universal Aquarius and organic solution which allows for industrial treatment of CSG water would be Nylon being able to treat between a pore size 0.1 and 7.0, most membranes have thermal, chemical and mechanical properties of the polymer they are used to filter with such particles as

Figure 9: Membrane filters

  - Cold sterilization of beverages and pharmaceuticals
  - Separation of bacteria from water (biological wastewater treatment)
  - Effluent treatment
  - Separation of oil/ water emulsions
  - Pre-treatment of water for nan filtration or Reverse Osmosis
  - Solid-liquid separation for pharmacies or food industries

Figure 10: Membrane Filtration Units

- **Ion Exchange –** The reversible interchange of ions between a sold and a liquid in which there is no permanent change in the structure of the solid, mainly used in water treated helping to provide a method of separation for many processes involving liquid (Tosoh Bioscience, 2013). A sub category of this process is known as Cation exchange used to soften water, this process exchanges calcium and magnesium ions for odium ions, this process is essential to allow water to flow thought the treatment plant without calcium or magnesium scale-formation (GE Health, 2011).
  - Softening calcium, magnesium and iron replaced by sodium
  - Deionization all cations replaced by hydrogen (H+), all anions replaced by hydroxide (OH-)
  - Metal Removal iron, nickel, zinc, copper, lead, replaced by hydrogen (H+)
  - Nitrate Removal nitrates replaced by chloride
  - Dealkalization bicarbonate and carbonates replaced by chloride
  - Arsenic Removal arsenic V replaced by chloride Precious Metal Recovery: gold, silver replaced by chloride

Additional to these treatment methods are as followed in brief:

- **Osmosis -** Osmosis is a natural process that occurs in all living cells. Water permeates through a membrane that excludes suspended solids, dissolved salts and larger organic molecules (Great Water, 2013). Water molecules have a stronger tendency to escape from pure water than from a salt solution. Water flows through the semipermeable membrane from the pure solution to the salt solution in an effort to equalize the osmotic pressure of the two solutions.

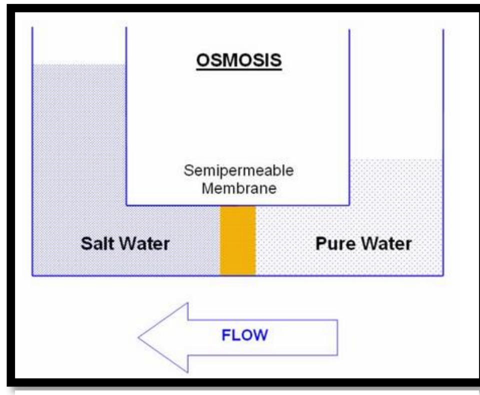


Figure 11: Osmosis Process

- **Reverse osmosis -** The above process may be reversed by applying pressure to the salt solution. In Reverse Osmosis, water from the salt solution is forced back through the semipermeable membrane to the pure solution. The process stops when the osmotic pressure of the increasingly salty solution equals the applied pressure. The specific process through which this occurs is called ion exclusion, in which a concentration of ions at the membrane surface from a barrier that allows other water molecules to pass through while excluding other substances (Great Water, 2013).

Figure 12: Reverse Osmosis System

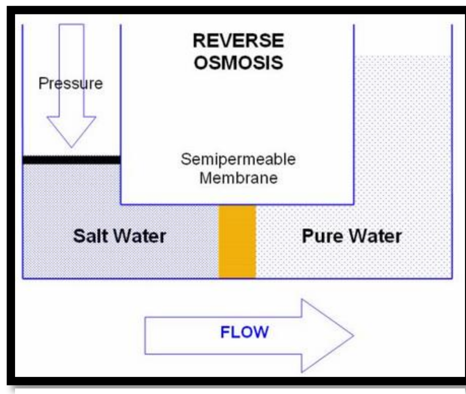


Figure 13: Reverse Osmosis Process

As seen in Figure 14 After the treatment of raw water there are two distinctive by products 'liquid ' and 'solid' each of which require the proper disposal method (Gay, Fletcher, Meyer, & Gross, 2012).

Following treatment, wastewater can be recycled for use directly at the well sites, or it must be disposed of by its return the hydrological cycle via the following method (Gay, Fletcher, Meyer, & Gross, 2012):

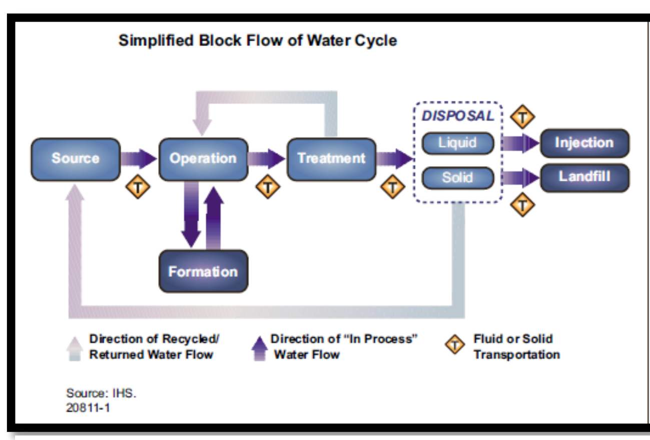


Figure 14: Water Cycle Block Process

Underground Injection – Is the placement of fluid deep underground into porous rock formations, such as sandstone or limestone, or into or below the shallow soil layer, this is attained by the boring, drilling a shaft, improving a sink hole or through a sub-surface fluid distribution system (EPA, 2013). Injection wells are constructed depending on the fluid being injected back and the depth of injection zone. This method is seen as feasibility as it could top up aquifers and potentially offset the ground water level decline in some areas that have occurred over the last 100 years (Australia Pacific LNG, 2013).

Figure 15: Injection Unit

Irrigation – The use from the treated water which is seen of highest value is the use to irrigate agricultural areas improving crop yields that feed and benefit the local communities. This helps localized agriculturalists, and breeders sustain healthy production though grain and fodder suppliers even in times of drought stimulating economic activity within the community traditionally within slower areas (Australia Pacific LNG, 2013) (CSIRO, 2012).

Figure 16: Irrigation System

Supplementing environmental flows – Treated water can be released into the waterways from water treatment facilities in such areas as Talinga for the Condamine River, increasing the amount of water available helping to secure water supplies in the region (Australia Pacific LNG, 2013). This will allow for adjoining land holders to access increased water availability and helping this areas river to return closer to a pre-development flow regime, leading to an increase in organisms, native fish and turtle populations. (CSIRO, 2012) (Australia Pacific LNG, 2013)

The CBM or CSG water cycle has been simplified by the ABC Corporation (2011) which is reflective in Appendix K being broken down into three main groups as follows:

- Where the water comes from;
- Storage and Treatment; and
- Where the water goes

The process from analysis to extraction and on to water treatment does not only being organizational wealth but helps to build both local, national and even global economic growth, not to mention that water that is treated helps local communities and the environment sustainability.

3. Coal Seam Gas Economic Outlook

The economic benefits which CBM or CSG bring to a globalized as well as localized economy and communities are explored in the below section.

a. Impact on global economy

By studying impacts of CSG from international records, and by observing the experiences and methods overseas countries have implemented during the development of CSG, further analysis can be brought forward which can help aid the decision in regards to CSG within Australia.

Natural gas supplies one fifth of the world's energy requirements. Japan is currently the largest importer of natural gas, being in the form of liquid natural gas (LNG). Other major LNG importers are South Korea, China, Taiwan, India, Spain, United Kingdom and the United States. **(Reference**) Most of the countries in the Asian pacific region have only just recently importing LNG. For example, China and India got their first shipments in 2006 and 2004 respectively. By 2015 the amount of LNG imported by these countries are expected to double. This is as a result of the constant growth experienced in the region.

Australia is currently the fourth largest exporter of LNG in the world. The country exports entirely to the Asia-Pacific region, with Japan accounting for almost all of the country's exports, as seen in Appendix M.

b. Impact on local, state and national economies

This section analyses the potential economic impacts relevant to local states within Australia, in regards to the development and production of CSG. Various scenarios have been showcased by statistical models produced by current economic status to overlook the benefits gained by developing a greater expansion of the CSG-LNG industries. Furthermore, negative outcomes such as employment decreases caused by CSG development have also been discussed in the following section.

2.2.1 Queensland

Over the past ten years CSG in Queensland has emerged as an important contributor to energy supply in eastern Australia (Williams, Stubbs, & Milligan, 2012). At a national level, over $140 billion in capital expenditure has been committed since 2007 on major LNG project's to quadruple Australia's LNG exports and establish the state as one of the world's largest LNG exporters. Of this sum, $45 billion was committed to coal seam gas-to-LNG projects on the east coast (Anglican Diocese of Brisbane. 2012).

In a recent study, CSG production in Queensland opens a promising future for the state, with an estimated 40,000 CSG wells that could be drilled over the next 30 years. There have been various proposed CSG projects in areas such as Surat, Bowen basins, Clarence-Moreton, Cooper and Galilee Basins (Anglican Diocese of Brisbane. 2012). However, these projects are still undergoing further investigation before any commencement of work is taken place.

With the downfall of the mining industry over recent times, CSG to LNG industries in Queensland alone opens opportunities for the state to regain financial stability locally, nationally and on a global scale. The economic impacts of the CSG LNG Industry in Queensland are likely to be significant. The Queensland Government stated from an economical study in November 2010 (Williams, Stubbs, & Milligan, 2012).

Based on the current economic position a medium-sized LNG industry producing 28.8 million tonnes per annum (Mtpa) CSG to LNG industry could:

- *Generate over 18,000 jobs in Queensland with 4,300 jobs in the Sturat Basin alone,*
- *Increase gross state product by over $3 billion (or 1%),*
- *Generate private sector investment of over $45 billion,*
- *Provide royalty returns of over $850 million per annum, which could help fund schools, hospitals and other vital services.*

With CSG currently at an early stage of development in Queensland, the large scale future potential CSG can offer has attracted many international resource companies such as BG, Sinopec, Tokyo Gas, CNOOC, Petronas, ConocoPhillips and Shell to invest in CSG's bright future (Williams, Stubbs, & Milligan, 2012).

With a strong international influence already developing, the Queensland government also suggested in the same statement that local businesses would flourish with the development of CSG industries in the community (Williams, Stubbs, & Milligan, 2012).

More investment in Queensland is great for home-grown businesses too. No matter what business you're in, investment growth is breathing new life into cities and towns. Already, a number of Queensland-based companies are winning multi-million dollar contracts, creating growth and employing new staff, trainees and apprentices along the way (Williams, Stubbs, & Milligan, 2012).

For every major contract awarded in the construction and production phase, smaller companies in the supply chain are able to diversify, grow and employ more people. Everything from manufacturing, drilling, research, operational maintenance, training and labor services, through to retail and hospitality services is in demand.

Manufacturing and agriculture industries would suffer a great loss of employment due to CSG's development. With the same study, it has been predicted that electricity, gas and water industries also would undergo a decrease. This could lead to these industries to increase the costs for their services. However, the increase of the mining industry in relation to CSG mass production clearly compensates for the reduced employment numbers in other industry fields. Once again this estimation is a base line scenario and may not be as severe as depicted in the Appendix L.

At such an early stage of development, further research is required due to the complex amount of different factors that need to be carefully overlooked by all involved and affected by further development of CSG. By undergoing further study, better knowledge and understanding could be brought forward to obtaining an economically sustainable acceptance of CSG and the benefits it has to offer in Queensland.

2.2.2 New South Wales

Although Queensland is regarded as the primary state for the production of CSG, with already various small scaled projects and CSG plants undergoing production. New South Wales has been considered to also be a potential region for resourcing CSG. The NSW economy, although may not scale to the same level as Queensland's CSG benefits, could also take advantage of what the CSG-LNG industry has to offer.

The industry has already begun miniscule projects in the North-east region of the state of NSW in the Sydney and Gunned Basin which produces approximately 6.2 PJ per annum. Potentially, these sites have the capacity to increase its production from 6.2PJ per annum to 210PJ per annum (Williams, Stubbs, & Milligan, 2012) . The figures indicate a significant jump of production and already create a vast amount of opportunities if further expansion were to commence.

There have been various studies performed and models produced to aid in visualizing the benefits of the industry for the state. A particular study carried out by Allen Consulting Group in 2011 assessed the impacts of the CSG industry in NSW. Their research produced the following estimations as a base scenario.

Allen Consulting (2011) estimated that the combined direct and indirect impacts of the development would:

- *Expand employment opportunities through increased economic activity throughout NSW, increasing to around 2,900 ongoing full time positions;*
- *Create 200 direct permanent full time positions on the project, and additional direct employment during construction peaking at 1,800 jobs in 2015;*
- *Increase the level of NSW gross state product (GSP) by 0.20% per annum, adding $15.2 billion to the state economy out to 2035;*
- *Increase the gross regional product of 'Northwest' NSW by some 3.2% per annum – equating to an annual increase of $470 million in today's dollars (retaining over half of the expected increase in NSW's GSP);*
- *Expand national incomes (gross domestic product) by an expected 0.04% per annum; and*

- *By producing an extra 5GL per annum of water from deep coal seams, the potential development could benefit agricultural production in the region by an average of nearly 1% per annum during the operations phase.*
  Opposition factors against the benefits would also impact the economy negatively, in such a similar way as stated for Queensland.

4. Coal Seam Gas Environmental Outlook

However, with every economic enhancement that is made through primitive fuel, there must be some consequence to the action. These are serious environmental risks from unconventional gas extraction, but ones that differ from the public perceptions of the threats portrayed in debates in the US and Australia (Carey, n.a)

a. Impact of CSG mining and extraction techniques

i. Climate change impacts

- During the next 50 year period there is a need to reduce global greenhouse gas emissions by half if we want to keep a global temperature increase below two degrees Celsius (World Energy Council 201.
- Methane emissions from coal contribute to increasing greenhouse gas concentrations (IEA Clean Coal Centre 2005).
- Methane, which is the main component of the CSG, is a potent greenhouse gas, with a global warming potential more than 20 times that of carbon dioxide (DIICCSRTE, 2013).
- During the preproduction, production and processing and transmission and distribution of CSG, fugitive emissions occur. Fugitive emissions are greenhouse gas emissions which concern the release of greenhouse gases through venting, leakages and (DIICCSRTE, 2013)Fugitive methane gas emissions from unconventional gas operations were assessed to be 4% - (IEA, 2005)8%, from initial drill to final use (Linn, 2013)
- However, in 2010-11, fugitive emissions from the Australian natural gas sector, which includes CSG as well as conventional gas, were estimated to be 10.5 million tonnes of CO^2-e (carbon dioxide equivalent) , or around 1.9% of Australia's National Greenhouse Gas Accounts (DIICCSRTE, 2013)

From experience in USA, According to Ian Duncan (University of Texas, Austin, 2012): "Gas production activities have a relatively minor impact on the air pollution in the Dallas Fort Worth area and that benzene levels are dominated by contributions from vehicle exhausts, vapor losses from gasoline stations, small engine exhausts, and industrial exhausts. In addition the benzene levels in Dallas Fort Worth have in general decreased while natural gas extraction has ramped up".

ii. Local health impacts

- Residents in the Tara gas fields of south-western Queensland have reported health impacts, with children being hardest hit (Linn, 2013). Symptoms were:
  - Headaches, duration up to months, pins and needles. It is not evident that any of the headaches have been associated with a specific medical condition (e.g. migraine) or a specific diagnosis related to a toxic substance (Department of Health, 2013).
  - Eye irritations – sore, itchy eyes experienced mainly when outside the home with symptoms settling when indoors (Department of Health, 2013).
  - Nosebleeds – predominantly reported in children; several presentations to the local GP in the study period, however GP did not report any findings on clinical examination (Department of Health, 2013).
  - Skin rashes – more commonly reported in children; one skin rash was identified by the public health physician as a common skin condition that would be unrelated to CSG activities (Department of Health, 2013).
- Based on the clinical and environmental monitoring data available, a clear link cannot be drawn between the health complaints by some residents in the Tara region and impacts of the local CSG industry on air, water or soil within the community. The available evidence does not support the concern among some residents that excessive exposure to emissions from the CSG activities is the cause of the symptoms they have reported (Department of Health, 2013).
- The air monitoring provided to the Department of Health was sufficient to assess whether the reported symptoms were related to CSG activities. However, the available data were insufficient to properly characterize any cumulative impacts on air quality in the region, particularly given the anticipated growth of the industry. It is necessary to assess those impacts according to health-based standards which are relevant to long-term (Department of Health, 2013).

iii. Land and waterway impacts

In popular media there are documentaries portraying of burning methane coming out of taps. Experts dismiss those documentaries because there is a problem of methane emissions from naturally gaseous aquifers and of failed well construction, not of fracking itself (Climate, Energy and Water Nexus Project, 2012)

Semi-rural residential areas, agricultural areas, or natural conservation areas are being industrialized, because CSG industry builds gas field infrastructure: concrete pads for the CSG wells, compressor units, and storage tanks; connecting roads and pipelines; and holding ponds and/or treatment plants for the "produced" water. This infrastructure criss-crosses the landscape and requires additional truck traffic for both initial construction and ongoing servicing.

Further, with the gas extraction comes "produced" water which is typically contains significant but variable concentrations of salts. Holding, separating, and disposing of these pollutants is a major task. Dominant components in CSG water are Sodium Chloride, Sodium Bicarbonate, and small levels of fluoride, calcium, magnesium, barium, strontium, and boron.

The salinity of CSG water is typically measured as the concentration of total dissolved solids (TDS) with values ranging from 200 to more than 10,000 milligrams per litre.

Below is an example of typical CSG water composition (Stream Ecosystem Health Response to Coal Seam Gas Water Release: Hazard characterization, 2013)

Typical water quality values from individual CSG wells within the one field (Company C, Site C1)

Parameter	Well 5	Well 12	Well 17	Well 22	Well 23	Well 49	Well 51	Coefficient of variation[a] (%)
pH	8.7	8.6	8.46	8.53	8.36	8.57	8.49	1.3
Electrical conductivity (µS/cm)	1305.5	14252.2	1413.7	1536.1	1483.0	1681.8	1707.3	144
Alkalinity (mg/L)	771.9	788.4	953.4	1051.5	811.2	912.2	882.0	11.4
Bicarbonate alkalinity (mg/L)	661.4	730.9	800.1	828.7	734.3	836.6	848.6	8.97
Total hardness (mg/L)	2.6	2.6	3.17	2.88	3.80	4.83	4.75	27.3
Boron (mg/L)	0.5	0.63	0.57	0.60	0.56	0.76	0.76	15.97
Chloride (mg/L)	30.5	40.4	43.9	58.22	57.0	63.4	71.4	27.5
Fluoride (mg/L)	1.3	1.68	1.56	1.51	1.53	2.12	2.10	18.4
Iron (mg/L)	0.6	0.18	0.25	0.28	0.22	0.37	1.41	92.2
Lead (mg/L)	0.1	0.04	0.67	0.03	0.05	0.30	0.22	114.3
Calcium (mg/L)	0.9	0.98	0.96	0.90	0.96	1.60	1.25	24
Magnesium (mg/L)			0.10	0.10		0.26	0.24	49.7
Potassium (mg/L)	1.8	1.8	1.90	1.99	1.96	2.38	2.22	10.8
Sodium (mg/L)	357.9	390.1	416.2	336.7	410.1	468.1	471.9	12.6
SAR	347.1	109.4	531.7		93.9	89.5	97.5	87.95

[a] Coefficient of variation = ratio of the standard deviation to the mean expressed as a percentage

Figure 17: Typical water quality value from csg wells

Table below shows Queensland CSG industry EIS and EA water quality data (raw CSG water) compared to relevant water quality guideline values. (Green shading = maximum observed value below guideline; Orange shading = guideline trigger value falls between the minimum and maximum observed values; Red shading = minimum observed value above guideline trigger value; No shading = no applicable guideline trigger value). Data from CSG companies. (Adopted from Stream Ecosystem Health Response to Coal Seam Gas Water Release: Hazardharacterisation, 2013).

Water quality parameter	Units	Min	Max	Guideline trigger value	Guideline description
Standard anions					
Sulphate	mg/L	0	25	400	Recreation (ANZECC 2000)
Chloride	mg/L	1	4680	175	Irrigation of sensitive crops (ANZECC 2000)
Nitrate as N	mg/L	<0.01	7.19	0.7	Aquatic ecosystems (ANZECC 2000)
Nitrite as N	mg/L	<0.01	7	–	
Bicarbonate (as $CaCO_3$)	mg/L	1300	2519	–	
Carbonate (as $CaCO_3$)	mg/L	55	750	–	
Fluoride	mg/L	0.1	16	1	Irrigation (ANZECC 2000)
Standard cations					
Sodium	mg/L	36	4280	115	Irrigation (ANZECC 2000)
Potassium	mg/L	0.1	78	–	
Calcium	mg/L	0.1	59	1000	Stock watering (ANZECC 2000)
Magnesium	mg/L	0	45	–	
Iron	mg/L	0	190	0.3	Aquatic ecosystems (ANZECC 2000)
Other properties					
Temperature (field reads)	deg C			20^{th} – 80^{th} percentile	
pH		7.0	9.9	6.5–8	Referential (DERM 2009)
Conductivity at 25°C	µS/cm	6	15618	325	Referential (DERM 2009)
Total dissolved solids	mg/L	79	11300	–	
Total suspended solids	mg/L	1	21200	6	Referential (DERM 2009)
Turbidity	NTU	1.5	1223	–	
Total alkalinity (as $CaCO_3$)	mg/L	100	6890	–	
Total hardness (as $CaCO_3$)	mg/L	3	83.2	–	
Total organic carbon	mg/L	6	36.1	–	
Additional anions					
Selenium	mg/L	<0.01	48	–	
Arsenic	mg/L	<0.001	0.02	0.24 (AsIII) 0.13 (AsV)	Aquatic ecosystems (ANZECC 2000)
Silica (SiO_2)	mg/L	0.003	51	–	
Sulphide	mg/L	<0.1	0.1	–	
Hydrogen sulphide	mg/L	<0.1	<0.1	–	
Bromine	mg/L	1	9	–	
Additional cations					

Aluminium	mg/L	0.005	84	0.55	Aquatic ecosystems (ANZECC 2000)
Barium	mg/L	0.19	5.5	–	
Boron	mg/L	0.02	96	0.37	Aquatic ecosystems (ANZECC 2000)
Cadmium	mg/L	<0.0001	0.215	0.0002	Aquatic ecosystems (ANZECC 2000)
Chromium	mg/L	<0.001	0.02	0.0001	Aquatic ecosystems (ANZECC 2000)
Copper	mg/L	<0.001	4.9	0.0014	Aquatic ecosystems (ANZECC 2000)
Nickel	mg/L	0.001	0.141	0.011	Aquatic ecosystems (ANZECC 2000)
Zinc	mg/L	<0.005	0.739	0.008	Aquatic ecosystems (ANZECC 2000)
Lead	mg/L	<0.001	0.28	0.0034	Aquatic ecosystems (ANZECC 2000)
Mercury	mg/L	<0.0001	0.001	0.00006	Aquatic ecosystems (ANZECC 2000)
Manganese	mg/L	0.002	14	1.9	Aquatic ecosystems (ANZECC 2000)
Molybdenum	mg/L	<0.001	<0.005	0.034	Aquatic ecosystems (ANZECC 2000)
Silver	mg/L	<0.001	<0.001	0.00005	Aquatic ecosystems (ANZECC 2000)
Strontium	mg/L	1	6.1	–	
Tin	mg/L	<0.001	0.03	0.003	Aquatic ecosystems (ANZECC 2000)
Phosphorus	mg/L	<0.01	0.38	–	

iv. Sub-surface impacts - groundwater quality and quantity

The activity of hydraulic fracturing ("fracking") can lead to previously unconnected strata becoming connected, with this in turn potentially leading to the pollution of clean water aquifers. Even where fracking is not employed the breakdown of well bore hole casings over time (or through seismic activity) can result in new cross-strata connections and possible contamination. The contaminants come from both the drilling/extraction chemicals and the many substances (potentially including heavy metals and radionuclides) previously locked in the coal seam itself (Linn, 2013).

From experience in USA, According to Ian Duncan (University of Texas, Austin, 2012), there is no scientific evidence supporting contamination of groundwater by hydraulic fracturing or related gas extraction activities [in the United States]. The evidence supports the argument that contamination predated and/or was unrelated drilling activity in all cases extraction (Energy and Water Nexus Project, 2012).

On the other hand, a CSG well is drilled down a long way, with further horizontal drilling possible along the coal seam itself. In its descent the drilling path passes through many strata. In many instances the well bore hole will pass through aquifers that are used by people and/or are vital parts of natural groundwater flows (Linn, 2013). Experts call for more rigorous before and after aquifer water quality testing to monitor the impacts of unconventional gas production on water quality (Energy and Water Nexus Project, 2012)

Further, to release the gas vast amounts of groundwater also need to be extracted. Such large scale water extraction can cause groundwater levels to drop significantly and hence directly reduce water availability to both humans and the natural environment. This groundwater may have taken millennia to accumulate but is being extracted in just a few years (Linn, 2013).

b. Legislative Responsibilities

The information contained within Appendix M shows the legislative requirement for major developed countries involved in coal bed methane projects. It contains the required legislation procedures to operate Coal bed methane, rights to certain operations, appropriate agendas valid licenses and code of practice.

Local and national experts in advanced countries take part in a significant role in the CMM industry making sure guideline of methane rights, project approval for leasing land, licensing and approving processes. These actions aim at enabling interaction between numerous stakeholders: between the coal lessee on one side, and surface land owners, the gas leaseholder, power generators and pipeline operators on the other side. The table below shows the current establishments and regulatory bodies in CMM development. The levels and roles of accountability over the advanced countries are shown below.

Selected CMM authorities and regulatory bodies recognize the technical barriers and policy ethos that need to be stated, and recommend appropriate actions that the governments need to take to scale up the growth and operation of CMM. These authority breakdowns can be found in Appendix N in which worldwide authorities are broken down showing the appropriate governmental department.

5. Coal Seam Gas Social Outlook

A lack of community engagement is viewed by many as the primary governance problem contributing to the social conflict surrounding the development (Pulling and Knight, 2003; Hindmarsh, 2010) during coal-seam gas exploration in Queensland, it has become obvious that there have been major communication failures between the coal seam gas industry and local community.

It has been documented that a large number of the community consider that they have been insufficiently informed of the planned exploration or provided with white lies and one sided truths. This renders them unable to gain an informed view of the mining developments on hand (Leser, 2011).

As a result of the lack of communication, all over the eastern states, people were raising concern about the rapid expansion of coal and coal seam gas developments. This caused multiple opposition groups to be formed, the major opposition groups listed below:

- -The Western Downs Alliance
- -Lock the Gate
- -The Basin Sustainability Alliance
- -Kyogle Group against Gas
- -Keerong Gas Squad
- -The Ngaraakwal Indigenous Association

The key concerns raised by these groups were: Environmental damage; the impact on water and the air quality; and the lack of landowner rights. Other concerns were about the current regulation of the industry and the coal-seam gas mining company's general lack of engagement with members of the public.

This is as a result of the Individuals and communities having motivations outside economic concerns. Lifestyle factors such as 'farming', 'rural life' and 'life on the land' are powerful factors of the way in which communities perceive and understand CSG development and the resulting impact

From sources taken from IEA (Reference) as per Appendix O it can be seen that the relative achievements profiled for socio economic potential in Australia, have been able to achieve a high standard in lines with Germany and Poland including the following relative reforms.

- Educational and institution curriculum
- Industrial policy
- Evolving changes in attitude due to economic pressures

6. Conclusion

Concluding this report, a number of findings can be derived from the knowledge obtained from literature research and practical experience. CSG opens advancement opportunities in the next phase of human progression towards a greener more sustainable society, moving away from coal which can be 70% dirtier than its sister coal seam gas. However, CSG is not just a better alternative than coal, but provides much needed economic development with socialistic arguments on both for and against its use at all levels through community, industry and government. CBM although overshadowed by social activist and lobbyist groups as 'Lock the Gate Alliance' saying, as one part of their report noted from the National Water Commission, "coal seam gas development could cause significant social impacts by disrupting current land-use practices and the local environment through infrastructure construction and access". It is undeniable that the industry creates has a lasting range of social and economic benefits worth over fifty (50) billion dollars in projects.

To help further the CSG industry acknowledgment that a united front needs to be enabled and an organization to better their process, they are should make aware of how a person can be affected in different circumstances. However, the reduction from social activists and lobbyist groups behavior is a possibility should organizational industry process both be transparent and flexible thus the following recommendations.

1. community engagement is viewed by many as the primary governance for limiting the social conflict surrounding the development of the CSG industry
2. Address key concerns raised around Environmental damage; the impact on water and the air quality; and the lack of landowner rights.
3. Enhance public engagement regarding current regulation of the industry and the coal-seam gas mining
4. Release treated water into waterways from water treatment facilities increasing the amount of water available helping to secure water supplies in the region
5. Release treated water into waterways from water treatment facilities increasing the amount of water available adjoining land holders to access increased water availability and helping area rivers, to return closer to a pre-development flow regime.

This study is not without its limitations. Firstly, university students conducted the study. Whilst, this should not hinder any outcome, if the study had been conducted by experienced academics with proper funding a more concrete study with a more defined outcome would have been obtained.

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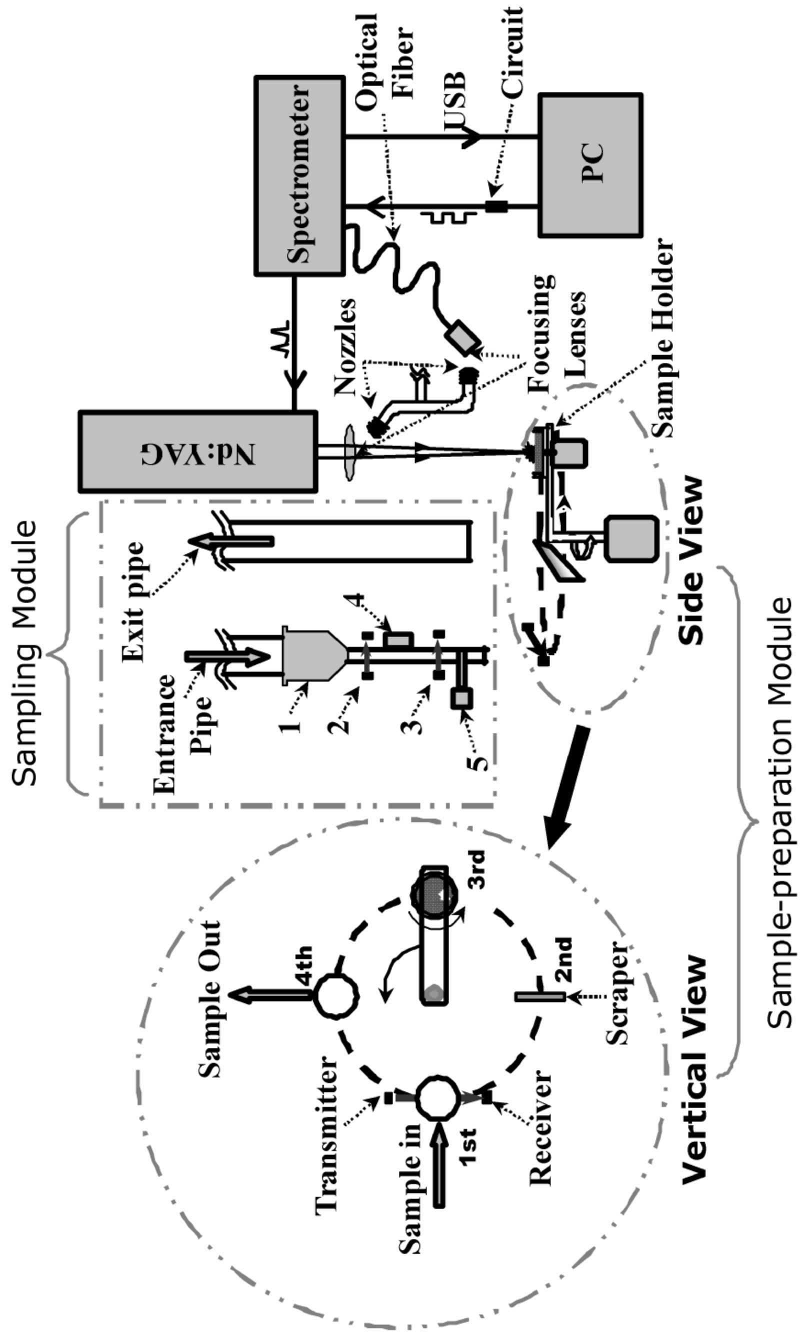
Appendices

Appendix A: Laser-Induced Breakdown Spectroscopy System

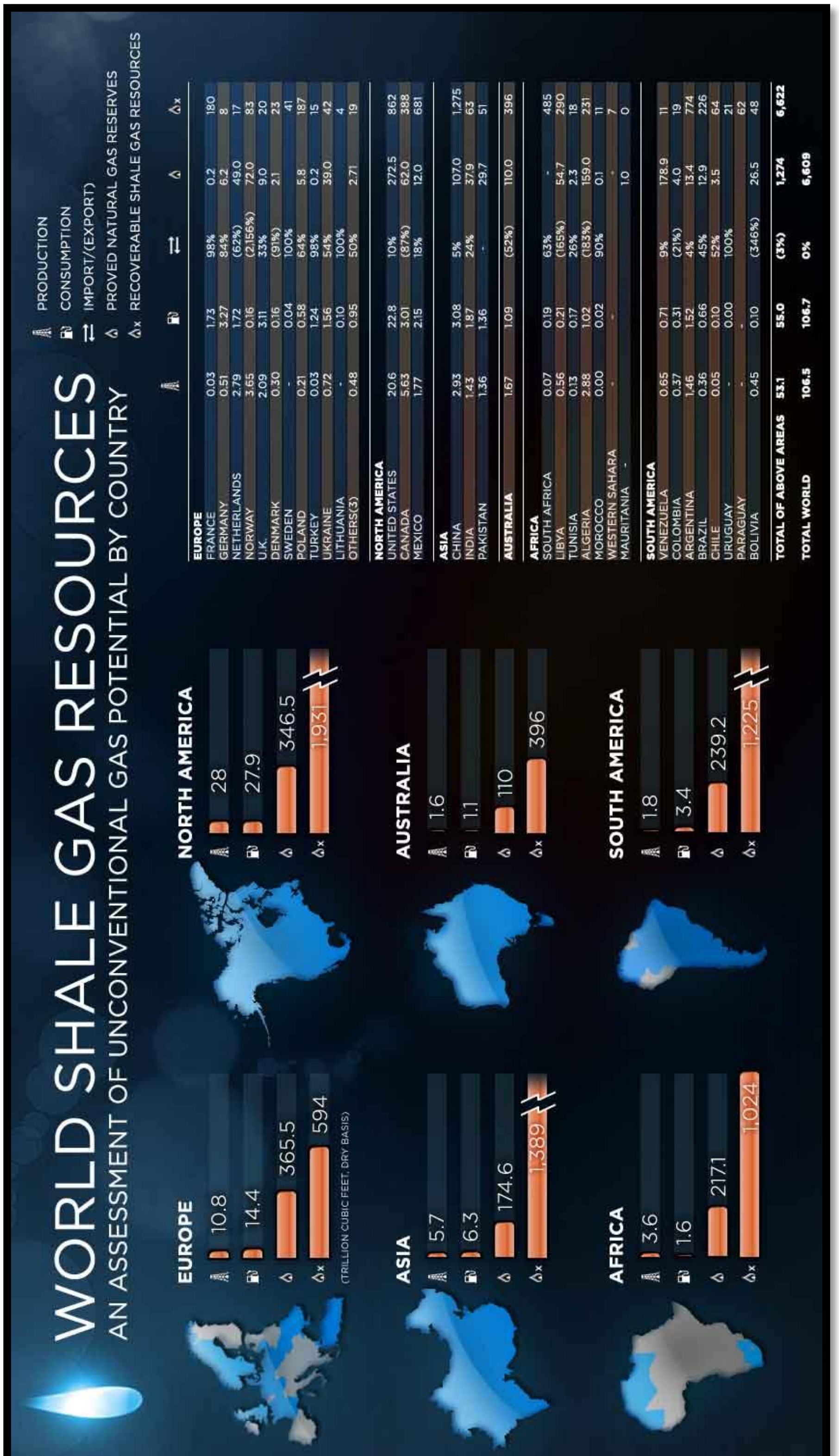


Appendix B: CBM Gas Composition

	Mole %	Fraction, x_j	Symbol	RD_{id}	Gross HV_{id}, Btu per ft^3
Hydrocarbons					
Methane	88.0230	0.880230	CH_4	0.5539	1010.0
Ethane	5.8240	0.058240	C_2H_6	1.0382	1769.7
Propane	3.2920	0.032920	C_3H_8	1.5226	2516.2
Isobutane	0.9360	0.009360	iC_4H_{10}	2.0068	3251.9
n-Butane	0.5370	0.005370	C_4H_{10}	2.0068	3262.4
Isopentane	0.2490	0.002490	iC_5H_{12}	2.4912	4000.9
n-Pentane	0.2360	0.002360	C_5H_{12}	2.4912	4008.7
n-Hexane	0.1490	0.001490	C_6H_{14}	2.9755	4756.0
n-Heptane	0.1890	0.001890	C_7H_{16}	3.4598	5502.6
n-Octane	0.0980	0.000980	C_8H_{18}	3.9441	6248.8
n-Nonane	0.0360	0.000360	C_9H_{20}	4.4284	6996.2
n-Decane	—	—	$C_{10}H_{22}$	4.9127	7742.9
Nonhydrocarbons					
Hydrogen	—	—	H_2	0.0696	324.2
Water	—	—	H_2O	0.0696	50.3
Carbon monoxide	—	—	CO	0.0696	320.5
Nitrogen	0.2620	0.002620	N_2	0.9672	0.0
Oxygen	—	—	O_2		0.0
Hydrogen sulfide	—	—	H_2S	1.5196	637.1
Carbon dioxide	0.1690	0.001690	CO_2	1.5196	0.0

Symbol	Units	Test	Standard
Hydrocarbons			
Methane	(C_2H_4)	mole % or fraction	GPA Standard 2261 and 2286
Ethane1	(C_2H_6)	mole % or fraction	GPA Standard 2261 and 2286
Propane	(C_3H_8)	mole % or fraction	GPA Standard 2261 and 2286
iso-Butane	(iC_4H_{10})	mole % or fraction	GPA Standard 2261 and 2286
n-Butane	(C_4H_{10})	mole % or fraction	GPA Standard 2261 and 2286
iso-Pentane	(iC_5H_{12})	mole % or fraction	GPA Standard 2261 and 2286
n-Pentane	(C_5H_{12})	mole % or fraction	GPA Standard 2261 and 2286
n-Hexane	(C_6H_{14})	mole % or fraction	GPA Standard 2261 and 2286
n-Heptane	(C_7H_{16})	mole % or fraction	GPA Standard 2261 and 2286
n-Octane	(C_8H_{18})	mole % or fraction	GPA Standard 2261 and 2286
n-Nonane	(C_9H_{20})	mole % or fraction	GPA Standard 2261 and 2286
n-Decane	($C_{10}H_{22}$)	mole % or fraction	GPA Standard 2261 and 2286
Nonhydrocarbons			
Hydrogen	(H_2)	mole % or fraction	GPA Standard 2261 and 2286
Carbon monoxide	(CO)	mole % or fraction	GPA Standard 2261 and 2286
Nitrogen	(N_2)	mole % or fraction	GPA Standard 2261 and 2286
Oxygen	(O_2)	mole % or fraction	GPA Standard 2261 and 2286
Hydrogen sulfide	(H_2S)	mole % or fraction	GPA Standard 2261 and 2286
Carbon dioxide	(CO_2)	mole % or fraction	GPA Standard 2261 and 2286

Appendix C: Global & National CBM geographical distribution
(World Coal Association, Coalbed methane emissions - capture and utilisation, 2005)



Appendix D: Global Recoverable Gas Reserves at end-2005

	billion cubic metres
Algeria	4 504
Angola	113
Benin	1
Cameroon	150
Congo (Brazzaville)	91
Congo (Democratic Rep.)	1
Côte d'Ivoire	42
Egypt (Arab Rep.)	1 894
Equatorial Guinea	73
Ethiopia	25
Gabon	30
Ghana	24
Libya/GSPLAJ	1 491
Morocco	2
Mozambique	127
Namibia	21
Nigeria	5 150
Rwanda	57
Senegal	11
Somalia	6
South Africa	10
Sudan	113
Tanzania	24
Tunisia	92
Total Africa	**14 052**
Barbados	N
Canada	1 633
Cuba	71
Guatemala	3
Mexico	412
Trinidad & Tobago	532
United States of America	5 866
Total North America	**8 517**
Argentina	439
Bolivia	740
Brazil	306
Chile	98
Colombia	140

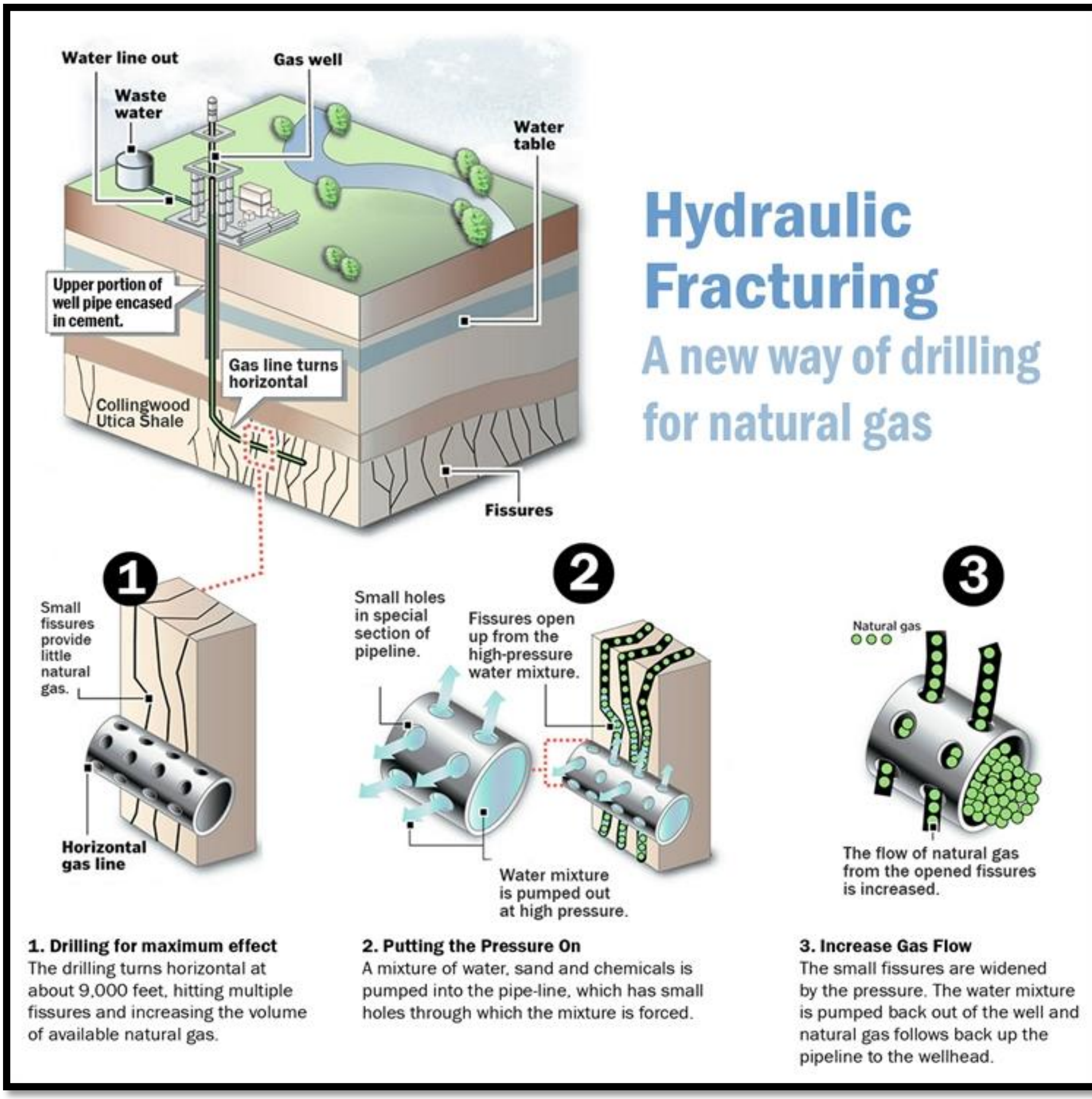
	billion cubic metres
Ecuador	10
Peru	338
Venezuela	4 315
Total South America	**6 386**
Afghanistan	50
Armenia	176
Azerbaijan	1 350
Bangladesh	436
Brunei	340
China	2 350
Georgia	8
India	1 101
Indonesia	2 754
Japan	51
Kazakhstan	3 000
Kyrgyzstan	6
Malaysia	2 480
Myanmar (Burma)	485
Nepal	N
Pakistan	807
Philippines	100
Taiwan, China	71
Tajikistan	6
Thailand	304
Turkey	15
Turkmenistan	2 860
Uzbekistan	1 850
Vietnam	365
Total Asia	**20 965**
Albania	2
Austria	15
Belarus	3
Bulgaria	1
Croatia	27
Czech Republic	4
Denmark	82
France	10
Germany	178
Greece	1
Hungary	67

	billion cubic metres
Ireland	10
Italy	170
Netherlands	1 256
Norway	2 358
Poland	75
Romania	121
Russian Federation	47 820
Serbia	48
Slovakia	15
Slovenia	N
Spain	3
Ukraine	787
United Kingdom	481
Total Europe	**53 534**
Bahrain	92
Iran (Islamic Rep.)	26 740
Iraq	3 170
Israel	34
Jordan	15
Kuwait	1 586
Oman	829
Qatar	25 633
Saudi Arabia	6 848
Syria (Arab Rep.)	298
United Arab Emirates	6 071
Yemen	479
Total Middle East	**71 795**
Australia	755
New Zealand	30
Papua New Guinea	428
Total Oceania	**1 213**
TOTAL WORLD	**176 462**

Notes:

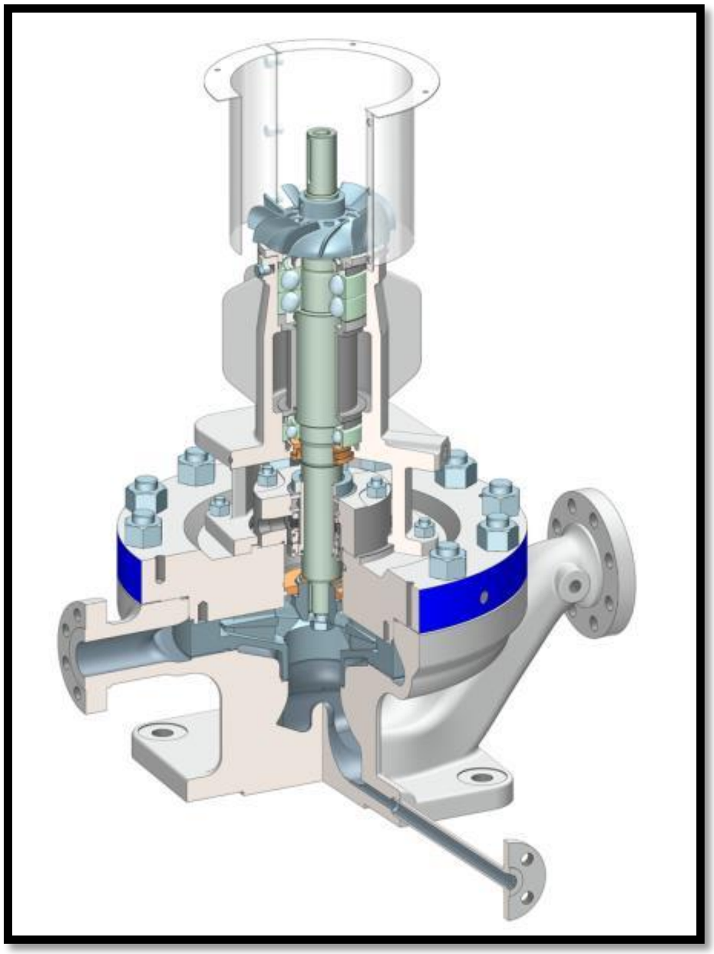
1. The relationship between cubic metres and cubic feet is on the basis of one cubic metre = 35.315 cubic feet throughout
2. Sources: WEC Member Committees, 2006/7; *Oil & Gas Journal*, 19 December, 2006; Cedigaz; *Annual Report 2005*, OAPEC; *World Oil*, September 2006; national sources

Appendix E: Hydrofracturing Diagram



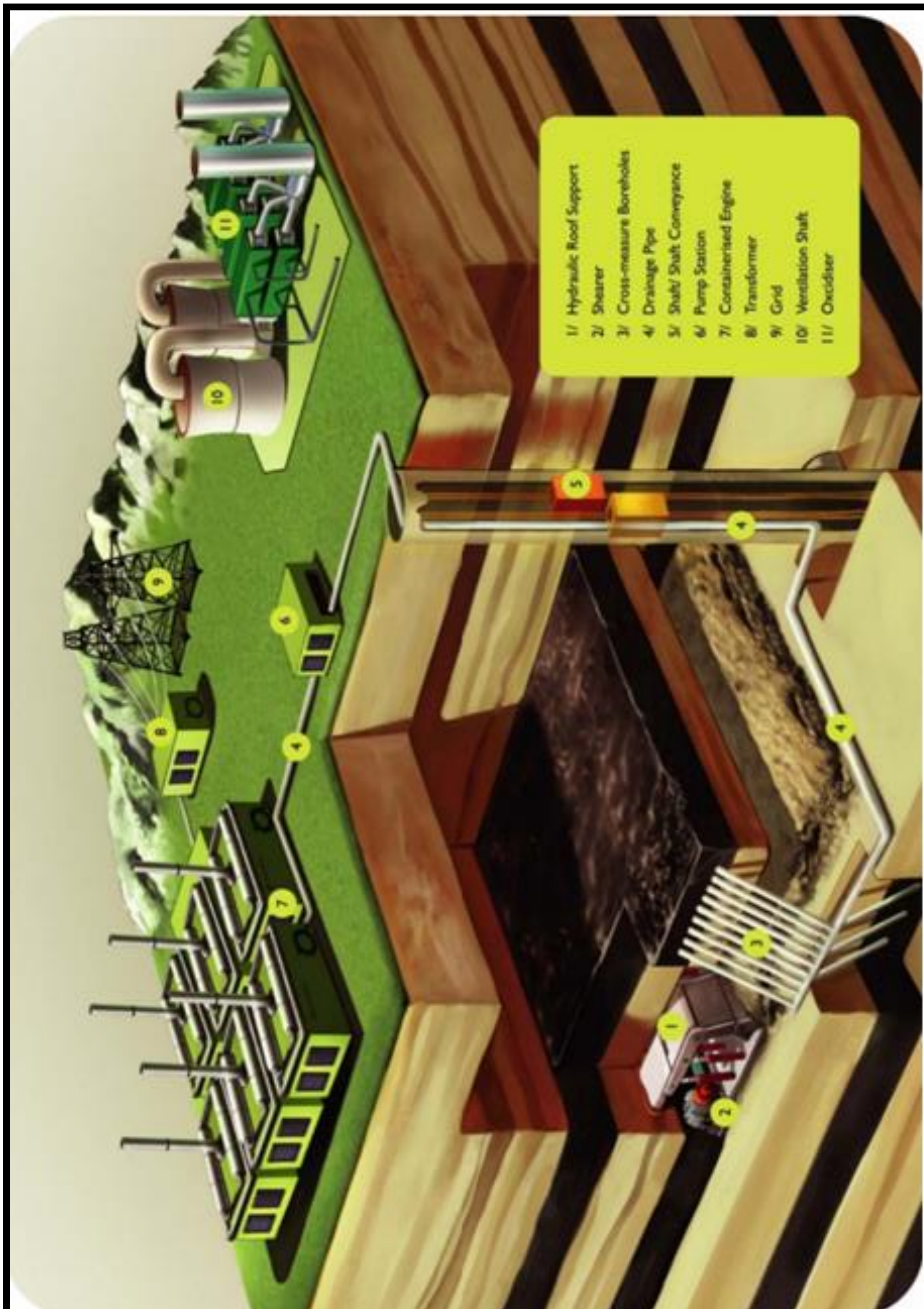
Appendix F: Vacuum Pump System Diagram

(Sulzer, 2013)

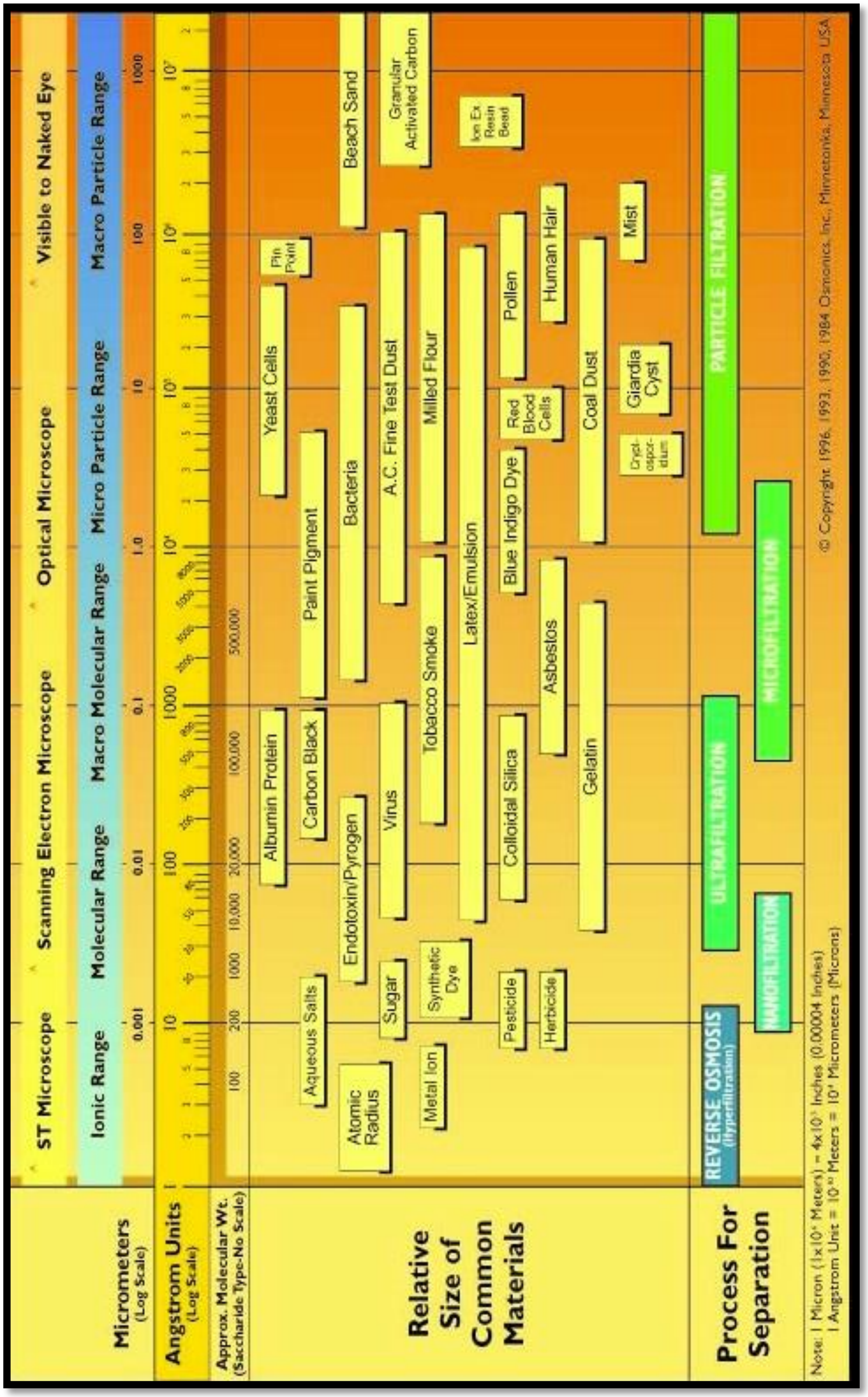


This pump is used for low-flow applications in refineries, oil and gas production, pipeline boosting, and offshore applications where space is confined. Its unique low-flow impeller-diffuser design provides gap-free coverage for low-flow, high-head applications.

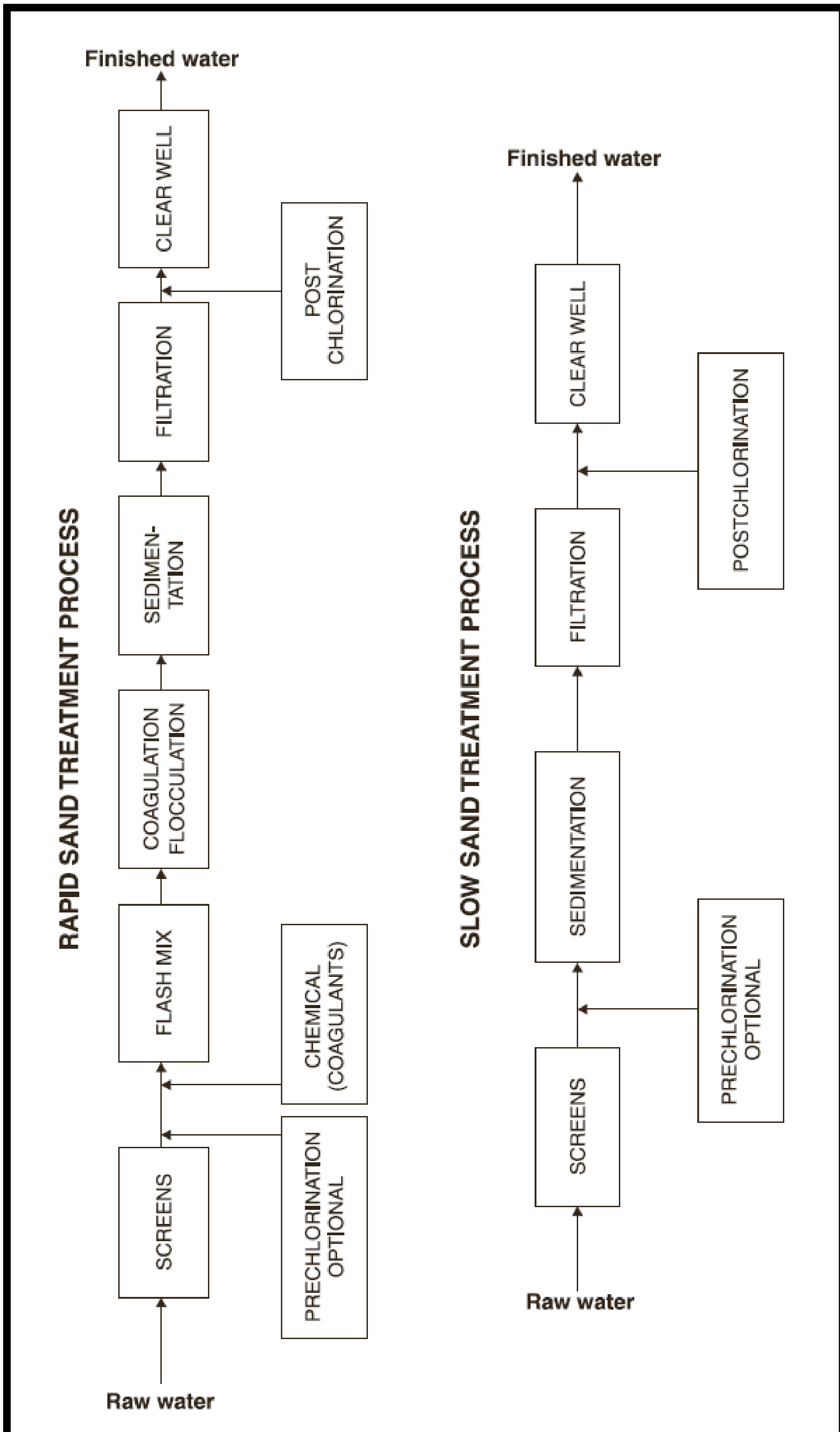
Appendix G: Plant underground methane drainage cycle



Appendix H: Filtration Spectrum



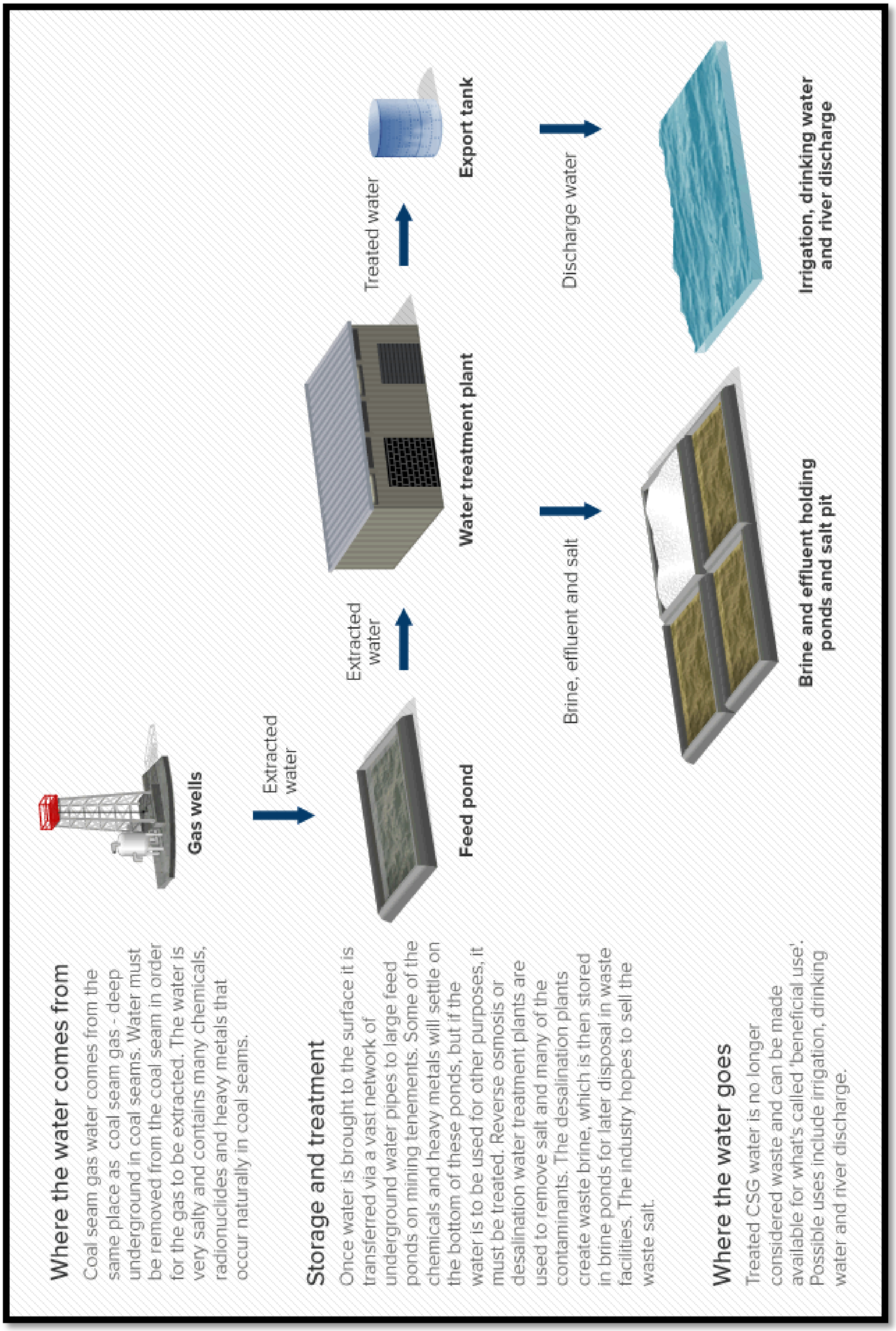
Appendix I: Rapid and Slow Filtration Processes



Appendix J: Membrane Filtration Breakdown

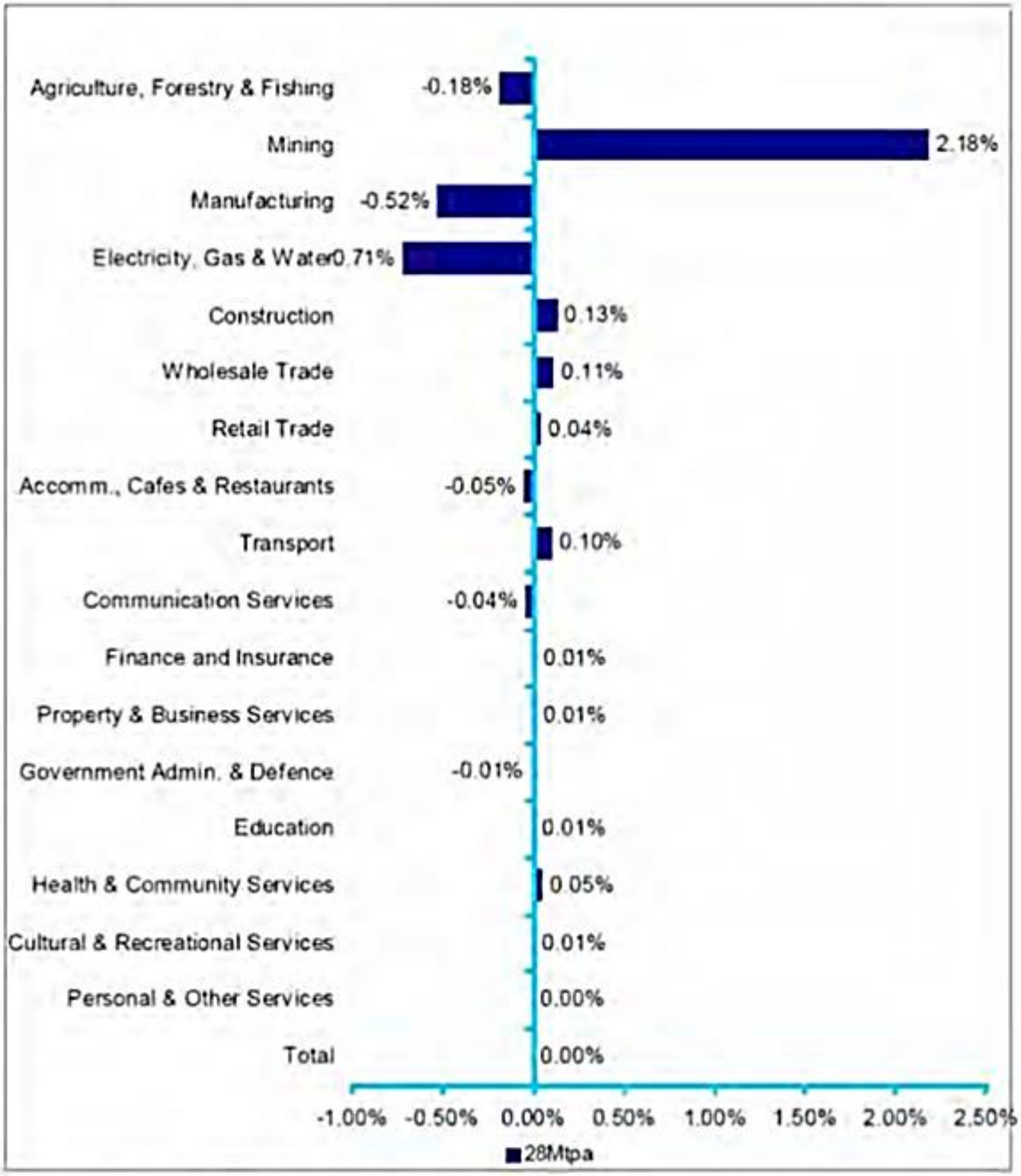
Membrane polymer	Sample applications	General compatibility	Hydrophilic	Hydrophobic	Pore size range available (µm)								
					0.1	0.2	0.45	0.8	1.0	3.0	5.0	8.0	10
Mixed cellulose esters (MCE)	General purpose Microbiology Particle Analysis	Aqueous solutions	✓										
Cellulose Acetate	General filtration Cytology Binding studies	Aqueous solutions	✓										
Coated Cellulose Acetate	Clarify solutions Prefilter	Aqueous solutions	✓										
Hydrophilic PTFE	HPLC solutions Clarify or sterilize aqueous/organic mixtures	Aqueous and organic solutions	✓										
Hydrophobic PTFE	Gas venting Clarify or sterilize strong acids or solvents	Non-aqueous solvents		✓									
Nylon	Filter sterilization Vacuum degassing HPLC solutions	Aqueous and organic solutions	✓										
Polycarbonate	Microscopy Beverage testing	Aqueous solutions	✓										
PVC	Particulate analysis Industrial hygiene	Aqueous solutions		✓									

Appendix K: Water cycle Treatment Breakdown



Appendix L: Annual Industry Employment Effects

Standard LNG Scenario Selected Average Annual Industry Employment Effects (% deviations from baseline)



Source: Econtech MM600+ simulation

Appendix M: Legislative Responsibilities

REGULATORY INFORMATION	COUNTRY
The authorized agenda governing resource licensing and ownership in Australia is complicated presently due to no national legislative agenda in place for Coal Mine Methane (CMM). Every state has its individual licensing and legislation measures. Mining Lease for coal in Queensland does not present rights to the enclosed coal seam gas. CMM preparation comes under the *Petroleum and Gas (Production and Safety) Act of 2004* and needs a valid Manufacturing License, which can synchronize with a Mining Contract covering the same area. A new routine had been released for Queensland government in November 2002 to state issues that arise where Coal Bed Methane (CBM), coal investigation and manufacturing activities may occur under different tenures approved over the same area. To implement the routine, a new *Petroleum and Gas (Production and Safety) Act* was agreed in 2004 to change the *Petroleum Act of 1923*. An Exploration License in NSW is essential before mining processes begin. If the owner of the contract wants to mine coal seam gas, a submission must be completed for the addition of petroleum in the Mining Contract. The *Mining Act of 1992* is the primary legislation governing mineral survey in NSW. CBM supplies are managed under the legislation for mineral supplies development in Victori.	Australia
There was controversy originally involved concerning the ownership of Coal Bed Methane (CBM) rights in Canada since	Canada

natural gas and coal come under other authorities. CBM rights together in Alberta and British Columbia (BC) now support the legal agenda for natural gas. The *Coalbed Gas Act* evidently features total CBM rights to the holders of natural gas and mineral rights (ASB, 2004). Canadian guidelines administer meeting with governments before development begins and affected stakeholders (CAPP, 2003). A possible manufacturer in BC must get Natural Gas and petroleum tenure rights before manufacturing. A particular coal gas contract is also necessary before production or survey of CBM (Blakes, 2006)[2].	
The authorized agenda for the economic operation of mine gas in Germany is established by the EEG and the federal law on mining. Survey, removal, and handling of mine gas are managed by the Federal Mining Authority. Throughout the process of the mine, the mining approval labels mine gas as being the land of the mining company. When the mining approval is out of date, a renewed license is required for a minimum of 30 years[3].	Germany
Section 29 (currently Section 45) credits was taken out before the Security and energy independence Act of 2007 was accepted in the 110thCongress (NBSA, 2007) However, the tax credits were restored and reviewed under the Energy Improvement and Extension Act of 2008 (IRS, 2009). Compensation taxes are given to state governments on revenues from natural gas sales. Recovered Methane projects must obey with strict environmental criteria, particularly in environmentally near urban centres and delicate[4].	United States of America

Methane ownership in coal stays with the UK government; however it's given to the licensee when the methane is recovered. The rights to the methane gas are controlled by the Department of Business Enterprise & Regulatory Reform under the Petroleum Act of 1998 (Coal Authority, 2007). Petroleum Exploration and Development Licenses (PEDLs) are given in a series of "sequences," the current being the 13th Landward Licensing round, which agreed applications on February 6, 2008 (Oil and Gas, 2008a). Methane Development Licenses (MDLs) are utilized mainly for functioning mines. An MDL accepts approval to get gas "in the course of operations for making and keeping safe mines whether or not disused." It accepts no special rights, so it can join geographically with a number of PEDLs. MDLs usually cover much smaller areas than PEDLs usually cover much larger areas than MDLs; normally it covers one mine each, though the Coal Authority owns a license which covers the whole country (Oil and Gas, 2008b)[5].	United kingdom

Appendix N: Global Statutory Bodies

CMM authorities and regulatory body	Operations	State/local level	Country
Department of Industry, Tourism, and Resources; **Australian Greenhouse Gas Office;** **Department of Environment, Water, Heritage, and the Arts**	Licensing and authorizing	Federal	Australia
Queensland Department of Natural Resources and Mines; **New South Wales Department of Primary Industries Minerals**	Arrangement of licenses for CBM/CMM extraction and royalty payments; project identification and assessment support	State	
Natural Resource Canada	Authorizing and licensing trade and commerce in natural resources	Federal	Canada
Alberta Ministry of Energy; **British Columbia Ministry of Energy, Mines, and Petroleum Resources**	Authorizing and licensing	Provincial	

CMM authorities and regulatory body	Operations	State/local level	Country
Bureau of Land Management within the U.S. Department of the Interior	Management of U.S. public lands and leases on federal land	Federal	United states of America
U.S. Forest Service within U.S. Department of Agriculture	Administration of the national forests and leases on federal forest land. (*Does not address projects on private lands.*)	Federal	
Arnsberg Local Government / Dept. 8 Mining Industry and Energy	Mining authorization; designation of mine gas property rights; administration of exploration, extraction, and processing of mine associated gas	State	Germany
State Ministry for the Environment Nature Conservation and Reactor Safety	Project identification and assessment support	Federal	
Department for Business Enterprise & Regulatory Reform	Regulation of methane rights	National	United Kingdom

Appendix O: Relative achievements of profiled countries toward CBM and CMM

Relative achievements of profiled countries towards CBM/CMM

	Market potential			Economic potential			Socio-economic potential			Technical potential			Physical potential		
	Use of sound technologies and practices	Utilise existing economic incentives	Bilateral or multilateral agreements	Define gas property rights; create and expand markets	Reduce risk and failure rates of projects	Unsubsidised free gas market	Educational and institutional reform	Changes in attitude	Industry involvement in policy making	Government initiatives, CMM/CBM energy plan	Development and demonstration of new technologies	Implementing new technologies; continued research	Increased use of new technologies	Widespread use of new technologies	New technologies commonplace
China	X	X		X			X	X					X		
USA	X	X	X	X	X	X	X			X			X		
Russia	X	X	X	X			X	X							
Ukraine	X	X													
Australia	X	X	X	X	X	X	X	X	X	X	X	X	X		
Poland	X	X	X				X	X	X				X		
Germany	X	X	X	X	X		X	X	X	X	X		X		
India	X	X	X												
South Africa	X	X													
Kazakhstan	X	X													
UK	X	X	X	X	X	X	X						X		
Czech Republic	X	X					X	X	X				X		